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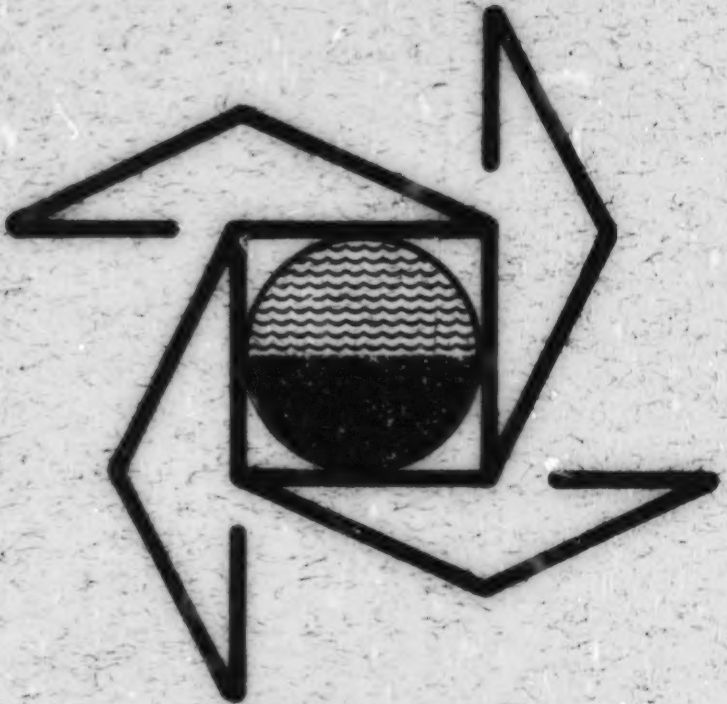
BEST MANAGEMENT PRACTICES FOR NON POINT SOURCE POLLUTION CONTROL SEMINAR



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BEST MANAGEMENT PRACTICES SEMINAR FOR NONPOINT SOURCE POLLUTION CONTROL

Ramada O'Hare Inn
6600 Mannheim & Higgins Road
Rosemont, Illinois
November 16 - 17, 1976

You are invited to attend a Best Management Practices Seminar for Nonpoint Source Pollution Control at Rosemont, Illinois, November 16-17, 1976. The purpose of the two day Seminar will be to provide guidance for section 208 planning and to describe some best management practices for nonpoint source pollution control.

The information was developed from three section 108 demonstration projects and one urban nonpoint source project. The data are useful to elected officials, consulting engineers, scientists, educators, and concerned citizens.

The accumulated knowledge will be presented through prepared papers by principal investigators and the proceedings will be published for distribution.

The seminar is sponsored by the U.S. Environmental Protection Agency, Region V, Chicago, Illinois.

Sincerely yours,

George R. Alexander, Jr.
Regional Administrator

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16. ABSTRACT

This report is a collection of technical papers presented at the "Best Management Practices for Non-point Source Pollution Control" - Seminar held at Ramada O'Hare Inn, Rosemont, Illinois, on November 16 and 17, 1976. The principal investigators of four Section 108(a) demonstration projects present their data and interpretation thereof, that has been collected on their respective projects through September of 1976. These projects include sediment/erosion control, land management, and urban runoff activities.

Federal, State and County officials give their agency views on Section 208 planning.

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FOR
NON-POINT SOURCE POLLUTION CONTROL

(Guidance for Section 208 Planners and Implementing Agencies)

A report on a Seminar

held at

Ramada - The O'Hare Inn
November 16-17, 1976
Rosemont, Illinois

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BEST MANAGEMENT PRACTICES
for
NONPOINT SOURCE POLLUTION CONTROL

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CALL TO ORDER

By

Ralph G. Christensen*

Ladies and gentlemen, I appreciate your attendance here today at this non-point source pollution seminar. I am Ralph G.Christensen, Chief of the Section 108(a) Program under P.L. 92-500. Section 108(a) provides for grants to support any State, political subdivision, interstate agency, or other public agency, or combination thereof, to carry out one or more projects to demonstrate new methods and techniques and to develop preliminary plans for the elimination or control of pollution within all or any part of the watersheds of the Great Lakes. Such projects shall demonstrate the engineering and economic feasibility and practicality of removal of pollutants and prevention of any polluting matter from entering into the Great Lakes in the future and other reduction and remedial techniques which will contribute substantially to effective and practical methods of water pollution prevention, reduction, or elimination. This program requires a grantee to provide a minimum of a 25% matching contribution to the total cost to the project.

Congress authorized to be appropriated $20,000,000 to carry out the provisions of this program. To date, there have been nine grants awarded under this section of the Act, three of which address the non-point source pollution problem.

Section 108 allows the demonstration of new approaches beyond those reflected in state established construction priorities, beyond those developed and demonstrated within the specified scientific and engineering subprograms, and beyond the few basin planning efforts that have been funded in the Great Lakes.

Section 108 implicitly recognizes that the approaches available in other EPA programs may not be adequate for controlling pollution in a basin of the scope and complexity of the Great Lakes system. It recognizes that the water quality of the Great Lakes is of broad national interest that may not be fully considered in setting state and local priorities. In response, it provides opportunities to demonstrate the value of approaches receiving low priority at the state and local level. Section 108 also implicitly recognizes that a piecemeal approach to wastewater management and treatment, while an important immediate step, cannot provide the systematic solutions required by such a large, complex environmental system as the Great Lakes.

Section 108 provides opportunities to supplement the piecemeal approach with system studies, plans and demonstration projects that broaden the focus beyond the boundaries of specific point sources, specific treatment technologies, and local jurisdictions. For example, Section 108 projects can address the full complexity of the multiple causes of pollution, both point and non-point, within a basin system; or the institutional barriers to arriving at areawide solutions in a politically responsible fashion; or the design of new treatment and control measures combining the results of new technologies and regulatory techniques.

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*Chief, Section 108(a) Program, P.L. 92-500, United States Environmental Protection Agency, Region V, Chicago, Il. 60604. Program Chairman.

Section 108, however, does not now provide a program of sufficient size to stand alone. It is clear that $20 million of demonstration projects, by themselves, would make little impact on the pollution problems besetting the Great Lakes. Section 108 projects must be used in addition to, in coordination with, and as a testing ground for, the use of authorities and resources available under present legislation. Section 108 provides opportunities to weld together specialized technical advances to yield new systems. It provides opportunities to fund new types of facilities in combination with treatment facilities and demonstrations supported by Section 201 and Section 105 grants. And it provides opportunities to channel these resources in ways that develop and strengthen implementing institutions.

Four of our Section 108(a) demonstration projects will be reported on during this seminar to provide some much needed data and information relating to non-point source pollution control and best management practices. This should be of value to all those associated with a Section 208 planning responsibility and also, implementing agencies.

I now introduce to you our Regional Administrator, Mr. George R. Alexander,Jr., who will welcome you, and also, be chairman of this mornings' seminar session. Mr. Alexander.

BEST MANAGEMENT PRACTICES FOR NONPOINT SOURCE POLLUTION CONTROL

Conference Held November 16 and 17, 1976

Welcome by

George R. Alexander, Jr.*

We welcome you to this conference on "Best Management Practices for Nonpoint Source Pollution Control."

It is a pleasure to see this large audience today and we appreciate the time you are taking out of your busy schedule to attend this conference.

We, in the Environmental Protection Agency, hope to share some practical, social, and technical information derived from demonstration projects funded from Section 108 of Public Law 92-500.

The agenda for this conference provides an overview of the nonpoint source pollution control mandate given to the U.S. EPA through Public Law 92-500. Among several sections of P.L. 92-500 which address the subject of nonpoint source pollution are sections 208, 303, 304, and 305. In addition to these sections of the Act, Sections 108, 104 and 105 provide for research and demonstration grants which can also address the nonpoint pollution problems.

Nonpoint source pollution is recognized internationally as a problem and is being addressed in the Great Lakes under the U.S.-Canada Great Lakes Water Quality Agreement. One of the references of this Water Quality Agreement is directed to inventory land-use activities and their pollution effects on the Great Lakes. To do this, we have implemented four land-use watershed studies in the United States and six watershed studies in Canada to prepare the information and remedial recommendations to best reduce and control nonpoint source pollution to the Lakes. Region V has committed $12 million to support these Section 108 demonstration projects and land-use watershed studies. Additional funds are being awarded in grants to designated Section 208 agencies to study and prepare Areawide Waste Treatment Management Plans for Implementation.

Russell Train, our EPA Administrator, stated in a recent speech that nonpoint sources of water pollution, such as runoff from croplands, urban stormwater, and strip mining, are becoming the single most important water quality problem.

Congress placed primary responsibility for the management of nonpoint source pollution in the hands of the States. This is as it should be. States and localities are better able to identify their problems as part of their over-all planning process than is the Federal government. We want to see localities, acting on a regional basis, getting more and more into the business of really facing up to these issues. Plans for solving such problems would be created and carried out through a political process in which both citizens and their elected officials--not experts or appointed officials--make all the basic choices and decisions. We want to encourage State and localities to tell us at the Federal level how we can help with programs that are conceived and implemented at lower levels.

---

*George R. Alexander, Jr., Administrator, U.S. Environmental Protection Agency, Region V, Chicago, Illinois 60604

To highlight some problems associated with nonpoint pollution, let me give you some examples:

(1) Two billion tons of sediment are delivered to lakes and streams annually from over 400 million acres of croplands, as well as large amounts of nitrogen and phosphorus from nonpoint sources, animal wastes from feedlots, and toxic pesticides.

(2) Between 5 and 10 percent of the total sediment load is estimated to come from 10 to 12 million acres of commercial forest harvested per year.

(3) Strip mining, which affects about 350,000 acres annually, results in the discharge of millions of tons of acidity and sediment.

(4) Urban sprawl, which consumes hundreds of square miles per year, generates sediment at an even greater rate than agricultural activities.

(5) The runoff of stormwater in urban areas accounts for pollution of waters with large amounts of toxic and oxygen-demanding materials.

Nonpoint sources of water pollution have become more than 50 percent of the total water quality problems. As site-specific sources of pollution are reduced by municipalities and industries, other sources gain in relative importance.

As a result of State and local interest, three demonstration projects have been implemented under Section 108 of P.L. 92-500. These projects will be reported on today by either the grantee project directors and/or their principal investigators. I will describe to you briefly the objectives of each project.

(1) The Allen County, Indiana, SWCD's Black Creek Project has been active now since 1972 and has one year yet to go. This project provides for a cooperative effort between the Allen County SWCD, the U.S. Department of Agriculture Soil Conservation Service and a team of scientists and engineers from Purdue University to demonstrate sediment reduction through use of land management practices. A socio-economic study is in progress to ascertain

what it will take to get landowners to implement best management practices for erosion sediment control.

At this time I would like to recognize:

--Congressman J. Edward Roush--

Congressman Roush was responsibile for calling a public meeting of local citizens in 1972. From this group of concerned citizens, the Black Creek Project of Allen County, Indiana was created. It has become the forerunner of several similar studies.

The Black Creek Project is rather unique--it takes the old tried and true conservation measures and applies the treatments to the land and assesses the environmental impact of these measures on water quality.

The second project is the Red Clay Project located in Douglas County, Wisconsin. The goal of this project is to initiate and implement an action program for soil erosion and sediment control in the Lake Superior Basin which will lead into a basin-wide program. Institutional arrangements and vehicles for intergovernmental cooperation between local governmental implementing authorities on an interstate basis will be established to solve the basin-wide red clay erosion and sediment problems.

The third project has been initiated with the Wisconsin State Board of Soil and Water Conservation Districts and is the Grantee for a project in Washington County, Wisconsin. Their project is to demonstrate the effectiveness of land control measures in improving water quality, and to devise the necessary institutional arrangements for the preparation, acceptance, adoption, and implementation of a sediment control ordinance applicable to incorporated and unincorporated areas on a county wide basis.

I hope the progress reports presented today will benefit you in your planning activities. I appreciate your attendance here today. If we can be of assistance to you during the day, please contact Mr. Ralph Christensen, Mr. Joseph Tynsky or Mr. Carl Wilson who will be happy to help you.

U.S. EPA OVERVIEW OF SECTION 208 PLANNING

By

Joseph A. Krivak*

I appreciate the opportunity to participate in this conference for a variety of reasons. First, I did have a small role in the inception of the Black Creek Project, which to a great degree, is serving as a case study for this seminar. Second, because the next year is a critical one as far as areawide planning is concerned: when decisions must be made between EPA/States/regional groups regarding the planning process is important. And third because there is a message that EPA needs to tell. To let the planners and the decision makers know what is expected before the process is completed not after the plan is delivered.

Frankly, I harbor a healthy skepticism about planning -- one born from experience. And also reaffirmed within the last week by a review of the first two 208 plans which have been completed. We have received preliminary reports, two of the initial fourteen. The brief review made, strengthened my belief about the kind of message EPA should put forward to State and Area 208 at this point in the planning process. It is not one of technical data collection and analysis — by and large, I think that is being done. If anything it may be that we are spending too much time and money on that part of our task. My message instead focuses on our need to get tangible results from the 208 planning process.

The first principle I would like to share my thoughts on is: "Don't spend too much time concerning yourself about how planning is conducted, but worry a great deal about whether it works." Experience has shown that the sophistication of the planning system often bears very little relationship to the results achieved. Now let's translate this into a common example. One of the biggest problems planners have is separating their recommendations from the decisions that both public and private decision makers must make. And so while we often go through a very elaborate set of planning gymnastics, those gymnastics often fail to provide the basic information needed by the person or group who is faced with making the decision.

The second principle is to plan sufficiently to produce specific targets, then quit. Another way of expressing the same idea is to establish specific objectives — which can be realtered within the time and resources available. EPA gave meaning to this principle in the non-point source phase of the water quality management program. You were asked to identify your top priority NPS problems and concentrate on only those in the 208 planning process. Sure, it's nice to have a complete data base -- but not necessary. Sure, it's nice to have sophisticated modeling everywhere -- but if we did that it would waste both time and money.

The third principle is: insist that the plans result in a commitment to specified outputs for accomplishment. If I were going to make a guess on what will be the biggest weakness in the 208 plans when they are completed -- failure in this respect would be my choice. Too many planners think their job is done with that set of recommendations they produce. No 208 plan should be considered completed until -- for the priority problems identified -- the physical dimensions of the problems and the technological and management means of solving them together with the institution responsible for getting the job done are set forth.

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*Chief, Non-point Sources Branch, Water Planning Division, U.S. EPA, Washington, D.C. 20460

The final set of principles I would set forth is not for the planners but for the decision makers. The people who hired the planners to get the job done: (1) You have a major responsibility in seeing that the proper goals and objectives are set. If there is one major problem that most planners fail, it is their inability to develop a plan when they don't know what they are planning for. And, I might add, those two plans I looked at last week suffered from that weakness. And your other responsibility is keeping on top of the planning process -- "don't waste time with planners who cannot deliver results."

In a nutshell, that's the simple basic management guidance that EPA offers you. Sure, there are complex regulations and jargon that may be difficult to understand, but the job you have can be done if these principles are followed.

NACD* VIEW OF SECTION 208 PLANNING

by

William J. Horvath**

I would like to briefly state that the National Association of Conservation Districts has seven concerns for the 208 planning process. These are:

(1) That the plan have local involvement in its development, including conservation districts.

(2) That the plan be implementable - NACD feels this requires the practical approach we have utilized in the district movement.

(3) That a vigorous educational program be undertaken with landowners and others to gain acceptance by those who must implement the plan and those landowners affected.

(4) That cost-sharing be available for application of Best Management Practices (BMP's).

(5) That adequate funding be made available for securing the necessary technical assistance for applying BMP's.

(6) That a continuing research program be undertaken to provide the necessary information to determine the effects of BMP's on water quality.

(7) That conservation districts have a major responsibility as a designated agency for plan implementation, and that state soil conservation agencies provide the necessary coordination of that effort.

---

*NACD - National Association of Conservation Districts

**Upper Mississippi Representative, National Association of Conservation Districts, Stevens Point, Wisconsin

EXTENSION SERVICE VIEW OF SECTION 208 PLANNING

by

E. P. Christmas

It is indeed a pleasure for me to have the opportunity to meet with you this week and to discuss with you my views as to extension's role in the 208 planning process and non point source pollution control.

To set the stage for my comments relative to extension's role in this endeavor, I feel that I should first describe the Cooperative Extension Service as I view it and tell you a little about its mode of operation.

The Smith-Lever Act of 1914 was the third of three major Public Laws which brought about the development of the Land-Grant College with its agricultural research and extension education activities in the United States. This act provided for the formation and support of the agricultural extension services at the land grant institutions across the country for the purpose of disseminating useful and practical information in agriculture and home economics.

Over the years, the Extension Service has undergone a number of changes in organizational arrangement, program priorities and methods of disseminating information. However, a number of characteristics have changed little since their design in 1914 to meet the original intent of the Act. They are just as relevent today as they were 60 plus years ago. I feel that a discussion of a few of these will be quite helpful in understanding how and why the Cooperative Extension Service functions as it does.

One of the great strengths of Cooperative Extension is its bottom up form of organization. The vast majority of the Extension Service staff work directly with their clientele in the field. This phenomenon can best be illustrated by looking at the distribution of Extension personnel in 1976 on a national basis as follows:

	Number	Percent of total
1. Federal Staff		
a. Extension Service, USDA	191	1%
2. State Staff		
a. Directors and Administrative Personnel	440	3%
b. Subject Matter Specialists	4,131	24%
3. County Staff		
a. Program Leaders & Supervisors	702	4%
b. Area Agents	1,413	8%
c. County Agents	10,037	60%
Total	16,914	100%

In reality, all Extension personnel except 1.a and 2.a above are in constant contact with the clientele which they serve.

Most Extension program priorities are established at the local or county level. This is accomplished by involving County Extension Boards, program and/or commodity committees, farm organizations and other special interest groups present in the local community in the program planning process. If local people have a part in planning the extension program, they will support it and see that it is carried out successfully. Participation in these Extension education programs is voluntary and open to anyone who can benefit from them.

The method of financing the Cooperative Extension Service is an important contributor to its success. Joint funding involving federal, state and county governments is common to all states. Nationally, distribution of funding is approximately 40% federal, 40% state and 20% county. Indiana, however, has one of the highest levels of local support in the country of approximately 50% of the total field staff operation.

A knowledge base for Extension education is a necessary condition for the successful transfer of useful and practical information. The Land Grant Universities have played a unique role in this respect. The fact that the technology to be disseminated has been developed or tested at the local Land Grant University is an important factor encouraging its application. The County Extension Agent is his communities direct link with the Land Grant University and its knowledge resource base. This close tie assures programs based on up-to-date, scientific information and facts rather than emotion. It should be emphasized that the role of the Extension agent or specialist should be to help diagnose problems and recommend feasible alternatives for dealing with them. The clientele are not told which alternative to select nor given any incentive to take one particular course of action over another, but through the acquisition of unbiased-factual information can make sound decisions relative to their alternatives.

The Extension Service is not a regulatory agency, but it does inform people of regulations and of their options in meeting these regulations.

This brings me to my views on Extension's role in the 208 planning process and non-point pollution control. Some State Cooperative Extension Services are working very closely with their states "208 planning agency" in the development of educational programs related to 208 planning. The Extension Service has a responsibility to provide information to the agricultural community on the 208 planning process. This information should be of such a nature as to fully explain the 1972 Federal Water Pollution Control Act (P.L. 92-500), its purposes and goals. As a part of this type of educational program, the agricultural community should be encouraged to actively participate in the planning process.

In Indiana, a committee has been organized to provide guidance and direction for Extension Education programs in water quality management and Non-Point Pollution abatement programs. This committee is composed of extension and research personnel from Purdue and representatives of other agencies interested and working in the water quality area. The committee will also assist in drawing together information to assist Excension agents and others as the 208 planning process is carried out and in identifying areas needing additional research effort to back-up the extension program.

At this point, I will assume that the "best management practices" approach to reducing runoff is selected. If this is the case, the Cooperative Extension Service can then mount an educational program to acquaint agricultural producers with the various alternative "best management practices" and the corresponding advantages and disadvantages of each. The use of demonstrations, perhaps established as a joint endeavor of the Extension Service, Soil Conservation Service and the local Soil and Water Conservation District, could be very helpful in showing the value of the various "best management practices". The agricultural producer can then select those practices which best fits his operation and still effectively control runoff of contaminates.

In summary, the key to the success of Extension has been its unique structure as a partnership of the Land-Grant Universities, Federal, State and County governments, with strong guidance from those it serves in the establishment of program priorities. The system has survived because of its objectivity and ability to use research based facts and logical relationships to solve clientele problems.

The role of the Cooperative Extension Service in the 208 Planning Process involves two areas of activity; first, an educational program to inform the agricultural community of the 208 Planning process and secondly, to acquaint agricultural producers with alternative "best management practices" and their application.

USDA - SCS VIEWS ON 208 PLANNING

by

Cletus J. Gillman*

It is a real pleasure for me to meet with you today to discuss the views and responsibilities of the U.S. Department of Agriculture and the Soil Conservation Service on Section 208 Planning. Concerning the views of the Department and the Agency, I can say that they are identical. Concerning responsibilities for assistance, I will primarily relate to the Soil Conservation Service, but will talk briefly about Departmental policy which guides all agencies within the Department.

USDA and SCS both can be classed as strong and willing advocates of the objectives of the Federal Water Pollution Control Act, particularly the control of nonpoint source pollution under section 208.

The Secretary of Agriculture, along with other federal departments, in 1973 entered into an agreement with EPA to assure maximum utilization of existing programs in assisting with 208 planning and implementation. This agreement further established the basis for more specific agreements by the various USDA agencies with EPA or with other planning entities carrying out 208 planning.

All Departmental actions since that time indicates the sincerity behind the agreement. Last year the Secretary established policy that would assure proper coordination of USDA assistance to this effort. Agencies in each state met to designate or establish a so-called "mechanism" to achieve this coordination. In most states, the previously established USDA Rural Development Committees, or one of their task forces, were designated to become this coordinating mechanism. As an example, in Indiana the Land Use Task Force (within the State Rural Development Committee) was so designated and is actively carrying out this coordination. USDA agencies represented on the Land Use Task Force include Agricultural Stabilization and Conservation Service, Farmers Home Administration, Forest Service, Extension Service, Rural Electrification Administration and SCS.

Meanwhile the Soil Conservation Service was designated to have a "lead agency" role in USDA, and further requested to set up the necessary coordination. In most states the logical and eventual move was for SCS to chair the committee for coordination. Prior to these Departmental actions, SCS established policy to maintain effective liaison with EPA at the national, regional and state levels.

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*Speech by Cletus J. Gillman, State Conservationist, USDA Soil Conservation Service, Indianapolis, Indiana at the Best Management Practices Seminar for Nonpoint Source Pollution Control, Chicago, Illinois, November 16, 1976.

With this brief discussion of the broad policies which establish a basis for effective cooperative assistance, I will get more specific on SCS responsibilities, capabilities and actions.

The Soil Conservation Service believes that the objectives of the Environmental Protection Agency in carrying out 208 planning are worthy and that, because of our authorities and capabilities, we should be an active participant in the teamwork that is essential for this program to produce beneficial results.

Our basic agency authorities and programs do allow us to participate fully in nonpoint pollution control planning and implementation. SCS was organized in 1935 to do the very thing we're talking about today -- use of conservation practices to control the erosion of soil. Today we relate this more specifically to reduction of sediment for water quality improvement.

Over these forty years we have developed an agency whose strength is in its technically qualified people in the field of soil, water and plant resources. We have developed an ability to work effectively with people at all levels, but primarily at the local level to the agricultural community. Programs have been developed which provide great flexibility, both in type of assistance and clientele or area that we can help. All of this can be extremely important during both the planning and implementation stages of 208.

We have always worked directly with and through soil and water conservation districts in carrying out our conservation activities. We attribute much of our success -- certainly our acceptance -- to this excellent, long-standing relationship. In 208 assistance, we intend to follow this procedure of working through districts and according to their priorities. We join NACD in encouraging districts to become involved in 208. Districts can be of tremendous assistance in fostering public participation, in both planning and implementation.

You may wonder, if SCS and SWCDs have been working at erosion control for so many years, why we have so much sediment being delivered to our streams today from agricultural land. I believe, sincerely, that there has been real success in erosion and sediment control. Unfortunately there are essentially no records to show levels of sediment delivered from farmland today as compared to several decades ago.

One thing we do know is that all sediment can not be kept out of the waters of America -- even if complete controls were possible on agricultural and developing lands. Perhaps 30% falls into this category. The other thing we know, and what is of real concern, is that about 50% of the sediment in streams and lakes does originate on farmland. This is a real challenge to all of us. It is something that we must diligently try to reduce. How much reduction there should be or needs to be, for meeting established water quality standards I don't know. No one else seems to know what the goals should be either. I am convinced that it is in this field that we have our greatest opportunity for reducing total suspended solids in our streams. I am further convinced that no one should have a pipe dream of holding in place a vast percentage of these soil losses from agricultural land. We will always have some sediment in our streams, some of it coming from farmland, and let's hope that no attempt is made to establish water quality standards so high that the agricultural industry will be stymied. There needs to be a continued understanding of balance among objectives for a quality environment and sound economics.

We have always worked with SWCDs on a voluntary program of landusers planning and applying conservation programs. There is much to be said for the desirability of achieving control through volunteerism. But we do recognize that this approach is not always as effective as desired. Some further legal requirements may be required. Many states have indicated, through legislation, that they believe so. Their recent experience seems to show that the actual or threat of legal requirements brings out more volunteers.

Experiences in states which do have erosion and sediment control legislation, and experiences in the 108 projects which you will be discussing later in this seminar, indicate that greater economic incentives - cost sharing - will be required to achieve a significantly accelerated sediment control program.

Now, specifically as to how we can and are helping in 208 planning for control of nonpoint sources of pollution. There is a significant data bank in our soil surveys and in our conservation needs inventories, and we have the capabilities to use this information in determining what the existing situations and needs are. We have a working knowledge of the Universal Soil Loss Equation and somewhat less knowledge on a formula for sediment delivery to streams. This accumulated information, and our knowledge of how to apply it, must be made available to the agencies developing 208 plans.

We further have a technical guide in each soil and water conservation district, which includes standards and specifications for time-tested conservation measures. We believe that these guides, along with current studies underway in 108 projects, will be your best guide to establishing "best management practices" at the local level to be used in implementation of 208 plans.

I will use Indiana as an example of how we are providing our base of information and our technical assistance to 208 planning agencies. Working through soil and water conservation districts, we have assigned two qualified conservationists, under an Intergovernmental Personnel Act agreement, to work directly on the staffs of two of the designated regional planning agencies. In the other designated regions, we have assigned a "lead" district conservationist to be primary liaison with the planning group, coordinating the assistance from the SCS personnel in the regions. At the state level, we have tried to work closely and cooperatively in an advisory capacity during the early stages of planning for action, and pledge to assist to the extent of available resources when actual planning for the remainder of the state gets underway.

We also serve, at the local, regional and state levels, on various technical advisory committees for guidance primarily in the realm of the agricultural situation, needs, and possible workable solutions. This advisory committee work is generally in close coordination with the supervisors of local soil and water conservation districts.

In each state, SCS has established and is carrying out a water quality evaluation program. Though the work to date, and the primary emphasis in the future, is on project type activities, the information gained will help assess the current situation on our streams.

Today, I certainly can't give you a testimonial on the ultimate value of our current assistance, except to say that we believe it is essential. We have no choice but to be involved! Your basic objectives and ours, and those of SWCDs, are supportive and in many instances identical.

To summarize, we believe that improvements in rural water quality will come about primarily from control of nonpoint sources of pollution. This is part of our agency's established mission -- it is our basic work. We have all the authorities necessary -- though short on people and money -- to carry out this essential work. We strongly support a cooperative effort to get the job done. I'm confident that we will change our operations to the degree needed to respond to present and future needs. We in USDA and in SCS stand ready to assist.

A State View of Water Quality Management Planning

Rex E. Jones
Indiana Stream Pollution Control Board

Non-point sources of pollution and their control are considered an integral part of Water Quality Management Planning. Water Quality Management Planning is provided for under Section 208 of the Federal Water Pollution Control Act Amendments of 1972.

I was very pleased to be asked to participate in this conference and I thank the Environmental Protection Agency for this opportunity.

It seems many times we speak in terms of numbers instead of talking in words. It is especially important when working with the public that we talk in understandable terms and not bureaucratic language. For instance, let's speak in terms of Water Quality Management Planning and not 208 Planning.

My background is in agriculture and I often relate aspects of my job back to the farm and the way we did things there. For instance, my father owns and operates a dairy farm and has been developing his operation for 35 years. Most farmers have a vision when they start out, of where they would like to be 30-40 years down the road. He won't know the future technology, the future economic picture, or exact size of his operation. Therefore, he must plan for his vision and build in flexibility to update his operation following economic and technical changes without having to scrap everything that has been accomplished along the way. I am sure each of you can relate this thought process of farm planning to your individual background. The actual thought process for planning is just plain common sense, no matter what your field of endeavor. Therefore, we feel water quality management planning is common sense for maximum utilization of our environment.

Since the enactment of the Federal Water Pollution Control Act Amendments of 1972, timing has been one of EPA's major problems. For instance, the States have had the responsibility of developing River Basin Plans under authority of Section 303 (e) of the Act. Each state has progressed at a different rate in the development of the River Basin Plans. Planning under Section 208 is dependent upon the completeness of the River Basin Plans. In the case of Indiana, we do not have completed River Basin Plans so the designated 208 agencies must either collect and analyze that information which is available or leave it out of the plan. If the plan is to be meaningful it must be complete. This requires additional manpower and expenses for the designated agencies. It does not do us any good to point the finger to who's at fault, because it is a problem where the fault crosses the paths of many people and agencies.

Therefore, it makes sense for us to assess where we are in the process and proceed to where we want to be on November 1, 1978. This is a great opportunity for each State to rethink their environmental program and determine where changes need to be made to maintain an effective and meaningful pollution control program. As with most problem situations we must ask ourselves who is going to do what, when, where, and how? These are difficult questions to answer and they apply to many different situations. It is a tremendous challenge to the people of this country.

Water quality management planning requires an interaction between a multitude of varying backgrounds if it is going to be successful. The problems cannot be solved by any one group in our society because the solutions to water quality problems will be a compromise between almost all segments of our society.

In Part 130 of the November 28, 1975, Federal Register, there is a discussion of the relationship of the Planning Process to other programs and I quote: "Because State and designated areawide water quality management planning will ultimately serve as the basis for implementation of essentially all programs under the Act, the relationship of and impact on other programs was carefully formulated in the proposed regulations."

This points up the importance of this program. The program should tie our other ongoing programs together so they are more meaningful and coordinated. It's similar to the mortar between the bricks.

It seems there is considerable confusion regarding the relationship of point source pollution to the pollution associated with nonpoint sources. I would like to discuss this for a brief moment. In Indiana, point source load allocations are based on low flow conditions (7-day 10-year low flow). During the low flow condition there are practically no nonpoint sources discharging into the stream, except for ground water which partially makes up the flow of the stream during low flow conditions. Therefore, point sources have the major impact during low flow conditions. When it rains one can expect surface or subsurface discharges entering the stream adding to the total flow of the stream. Depending upon quantity and intensity of the rainfall, nonpoint sources potentially become more significant to impaired water quality. As more flow exists in the stream, the point sources become less of an impact because of the dilution from additional water. Therefore, the more the rainfall the less impact on water quality from point sources and the more potential (depending upon geographic conditions) impact from nonpoint sources of pollution.

The control program for point source discharges is in place and functioning. Maintaining compliance, enforcement, and future limits in the permits are refinements that must be made in the program. However, control programs for nonpoint sources of pollution have not been set by the Federal or State government. This is a unique opportunity for the people to have real input to a planning process which eventually will determine who is going to do what, when, where and how to control nonpoint sources of water pollution. The control program is not developed yet and input from the people is necessary to structure an implementable and meaningful program to the people. If we do not involve the people early in the planning process there are serious doubts as to whether the program can be implemented.

To accomplish control of nonpoint sources of water pollution we must insert a high degree of common sense and reasonableness into the program. This leads into the utilization of best management practices in the solution of our problems. Best management practices will be determined by technical experts in their respective fields. For agriculture, the Soil Conservation Service is a likely candidate to be heavily involved in the determination of potential best management practices to be used in different parts of the country. We must look to best management practices being applied on a case-by-case basis depending upon the individual farm management practices and geographical and hydrologic conditions.

To produce and maintain an effective and meaningful water quality management plan on a statewide basis we must get the program close to the Governor's office. This is necessary in our State to relieve some of the bureaucratic processes if we are going to meet our deadlines for accomplishment. Without the cooperation and support of our key state administrators the program will not become effective.

The tasks of developing a good nonpoint source control program for our State are difficult. I feel the approach we take to develop a good program is a very important consideration. By approach, I mean the approach we take with people. For instance, instead of talking entirely of a control program, I prefer to speak in terms of problems and solutions. How can we help people solve their nonpoint source pollution problems? Relating to my own experience with the people of agriculture, they are, for the most part, quite willing to cooperate in solving their problems. However, they do not appreciate government people coming onto their land and telling them what to do. Instead a better approach may be to offer some technical alternative solutions to the landowner if he has a nonpoint source water pollution problem.

As I look around Indiana, I see a tremendous wealth of talent who could help solve many of our nonpoint source problems. For example, we have Purdue University, Purdue Extension Service, Soil Conservation Service, U. S. Geological Survey, Department of Commerce, State Planning Services Agency, Soil and Water Conservation Districts, and the people of our State. We must utilize this great reservoir of talent and I am sure the same is true of your State, if you will just open up and ask for their contribution.

The problems from nonpoint sources of pollution are extremely complex. As I mentioned earlier, approach is very important. Let's not just "point the finger" and say solve your problem because solutions are just not that easy. Instead, let's identify our problems, assess them, and determine how we can collectively best solve it. The problem must be viewed from different perspectives, such as, economic consideration, technical solution, social acceptance, and management capability. The solution to the problem after being discussed from each of the different perspectives would then be a compromise. Nobody will get their way 100%, but I believe we can come up with solutions that all perspectives can live with (a compromise).

A very important requirement of this plan is that it be implementable. To me that means acceptable by the people. The easiest way to make sure the people accept the plan is to have the people deeply involved in the development of it. This water quality management plan is not some agency's plan, but it is the people's plan.

If we want an acceptable nonpoint source control plan it will be necessary to make technical assistance available to the landowner. This involves the cooperative approach I spoke of earlier. Another important aspect is the financial feasibility and assistance that must be provided to the landowner. The farmer does not have direct control of the price of his product. There must be some financial assistance on best management practices if we want an acceptable program by the "agricultural community". If you have a knowledge of agriculture, I believe you would think this is reasonable.

One question I should answer in my presentation is the State's role in this effort. It is my opinion that the State's role should be one of strong leadership. Our objective in the Planning Section is to develop and maintain water pollution abatement programs that are effective and meaningful to the people of our State. To accomplish this the State must do certain things. We must provide equity on a statewide basis. The programs must be fair and equal to all parts of our State. The State must also provide consistency between designated agencies and the non-designated part of the State. This must be provided throughout the entire planning process. The State should provide guidance to the designated agencies to provide for consistency and equity. A fourth area of responsibility for the State is one of stimulating cooperation between local, regional, state, and Federal agencies. We are all working toward the same goal, hopefully, let's not fight each other. Each level of government has its responsibilities, these should be delineated and agreed upon by all parties involved. The State should lend support to educational programs to tell the story of what we are trying to accomplish and why. It is the responsibility of the State to integrate the designated and non-designated portions of the State to form the Statewide Water Quality Management Plan by November 1, 1978. Another important factor in this planning process is the continuous planning provision which makes the plan much more workable for future application.

In summary, I would say one of the keys to making the program successful will be the involvement of the people in the process before the alternatives are developed and the decisions are made. The people of each State must decide what kind of program they want and then support that program as a team. We must be a team.

A COUNTY VIEW OF SECTION 208 PLANNING

by

Reuben Schmahl*

When the white man came to America the Indians governed, there was no national debt, no taxes and best of all women did all the work. Into such a utopia white man moved in with the desire to make great improvements. Instead white man has been guilty of many misgivings, one of which has been the ravaging and misuse of our country's abundant natural resources. What has been maimed we are striving to reclaim with a sense of urgency.

It would appear, however, even in Biblical times mankind was plagued with environmental concerns. The story is related of God speaking to Moses saying, "I have some good news, as well as some bad news. The good news is that you have been chosen to lead the Israelites out of slavery in Egypt into the promised land. To accomplish this you shall part the waters of the Red Sea. The bad news is before you divide the waters of the Red Sea you will be required to file an acceptable environmental impact statement for review."

There is today a good segment of our people that have a firm determination to clean up our air and water and strive to halt, to a greater degree, abuse of our lands and to preserve our many natural resources. They have a conviction that we have not moved fast enough in dealing with those problem areas that affect our environment which include erosion prevention and pollution controls. Their great concern is whether existing programs need to be reviewed, amended and refined to improve their degree of effectiveness in reduction of environmental damages.

This sudden explosion of interest on the part of our public has brought about the creation of our Environmental Protection Agency which was established to deal with almost every conceivable aspect of the control and regulation of water pollution and improvement of water quality. Our nation has embarked seemingly on somewhat of a crash campaign against air and water pollution.

The likelihood of mistakes and miscalculations that surface in our efforts to resolve our dilemma may cause the mood of the American public to change and substantially effect the approaches being undertaken to achieve both clean water and air. I am of the firm belief that Soil and Water Conservation District Boards are logical entities to take leadership and accept responsibility to achieve reasonable and effective locally administered programs dealing with land use and water quality.

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*Chairman, Washington County Board of Supervisors, Jackson, Wisconsin
Chairman, Washington County Soil & Water Conservation Districts

As a member of a S.W.C.D. board, I wish to share some of my views on non-point pollution control and also relate a brief summary of activities to date of our EPA Study Grant underway in Washington County.

Public Law 92-500 (208), the Federal water quality act deals with "non-point" source pollution. "Non-point" source pollution is one that is not well defined as to where the true source originates while "point" pollution being one where the source is well defined. More specifically then "non-point" sources are materials that enter streams and lakes in a diffuse manner such as sediment, animal wastes, fertilizer and pesticides. "Point" sources which have to date received the most attention, are pollutants which reach water at a "point" such as municipal and industrial wastes discharge outlets.

Our efforts in "non-point" pollution control become very complicated. Any attempt to implement a corrective program involves many people and agencies of varied interests to carry on a study and implement acceptable objectives in a practical manner. Goals and objectives that have a reasonable public acceptance become rather complex becasue, although a reasonable degree of accord is reached amongst the various agencies (SWCD, County Boards, Federal, State and local governments), it becomes vital that the landowner's rights are not abused. The eventual success or failure of any study or research is wholly dependent on how accurate the detail and how the research was conducted and scrutinized by all agencies affected, as well as the response of landowners. Has there been seemingly insurmountable division of opinions? Do landowners believe financial subsidies are justifiable if they are to support a regulatory program which, in their opinion, is more in the public interest than totally designed to benefit them for their private gain? Public hearings on any tentative regulatory proposals should help to evaluate in the drafting of programs. I believe, however, prior to conducting such hearings, an all out series of educational programs must be conducted in an effort to completely inform the general public and certainly the landowners who are the people most directly affected.

As soil stewards, we have a tremendous task confronting us to overcome individual and group resistance to any regulatory or even suggestive measures to correct water pollution and to implement good soil practices. The very vocal and organized resistance to our highway improvement programs can be an example. SWCD boards have authority and a responsibility to conduct programs to control erosion of lands and sedimentation of our waters. Conservation districts have good organization and utilize effectively an extensive network of cooperative arrangements with federal and state agencies in planning, research, education, cost sharing and technical assistance. This arrangement has provided a very workable method for cooperatively establishing conservation practices on our land and has been used for about the past forty years.

Efforts, then, to control non-point pollution are not new, there is merely now a greater emphasis on accelerating a nationwide water pollution control effort and expanding it to include urban lands in addition to agricultural lands. To date, point source pollution has been receiving perhaps the most attention, and pressures to stop pollution of our waters from municipal and industrial wastes has been great. The mood of the American public, I believe, is new in that there is now a greater emphasis on local administration of government programs, whether they are social, revenue sharing, law enforcement or land use. In this context then SWCD's and related agencies are being viewed as the logical entities to take leadership and accept greater responsibility for the development and the administration of practical, effective non-point source pollution control programs. If local government with the help of many cooperating federal and state agencies fails to meet this challenge and opportunity for exercising home rule, our people may well become the victims of mandated controls by people in power far removed from the scene.

Presently in my home area the Washington County Soil and Water Conservation District is working with federal and state agencies under an EPA grant to monitor non-point sources of pollution in an agricultural watershed and a watershed which is changing from agricultural to urban uses at an accelerated rate.

The objectives of the district in a sediment management program are as follows:

1. Demonstrate a combination of voluntary and regulatory means of sediment management.

2. Develop standards of sediment management for use in land use and development.

3. Bring sediment management into urban development as well as farm use of lands.

4. Develop and use local leadership in land use planning and management.

5. Carry out an information program to promote wise land use and erosion control at all levels - individual, group and local units of government.

6. Provide a technical service to individuals, groups, and units of government in planning and implementing plans of land use and sediment management in both the urban and agricultural demonstration areas.

7. Explore the institutional arrangement in incorporated and unincorporated areas necessary to bring the expertise of Soil and Water Conservation Districts to bear on erosion and sedimentation problems of Washington County.

8. Determine the incentives necessary to accomplish the desired level of conservation application.

We all recognize that it is no simple matter to make decisions on reasonable and effective approaches to regulatory environmental controls. Some people will argue of programs not moving rapidly enough, while others tend to criticize the seemingly unrealistic, impractical and highly legal approaches being far too restrictive. We must, in my opinion, strive to seek a better balance between both extremes.

Our local SWCD members are working closely with an institutional study group from the University of Wisconsin. We are striving to develop institutional alternatives for non-point pollution and to prepare a suggested model of a possible approach to the problem which recognizes program trends in environmental and resource management in Wisconsin, particularly at a county level. The choice of alternatives will be based on the observation of legislative and administrative trends based on the ongoing planning and management programs as well as the nature of the non-point pollution source problems revealed.

As stated before, to document all the regulatory measures pertinent to the solution of the problem and the assessment of estimated costs of or apparent benefits from any corrective measures is obviously rather complex.

The land developer may by means of regulatory ordinances be obligated to comply with land conservation practices prior to any final plat approval. It is obvious that these costs will be reflected in the buyers purchase costs. On the contrary, acceptable land and water quality practices on agricultural land are more difficult to administer for several reasons.

1. The cost of controlling non-point discharges of sediments, nutrients, pesticides and chemicals associated with agricultural use may prove to be greater than the landowner is willing to spend.

2. In rural areas today there are many varied types of landowners:

   A. The land speculator who rents out his land and has absolutely no desire to preserve the land or is certainly most unwilling to expend monies for that purpose. His only purpose for owning the land is to realize a gain on its sale.

   B. The farm operator close to retirement age with no next of kin to continue the operation, who, therefore, is adverse to an expenditure of money on land use practices for the balance of his active farming years.

   C. Those landowners who desire to ignore land conservation practices in spite of any monetary payments. The wish to "do their thing" without restraints.

   D. Landowners who may have an interest but are burdened with a large debt and are reluctant to accept any greater financial burden that costly soil conserving practices may incur.

Hopefully, any remedial measures we formulate will have such a design that any group of people, whether from a rural or urban area, receive fair and equitable consideration.

Within the State of Wisconsin local governments are given the option of adopting floodplain, shoreland, land division, zoning and sanitary regulatory ordinances. They need to comply with or may even exceed those state standards. This allows for this type of ordinances being administered by local units of government. If local governments fail to exercise this option, states can enact regulatory rules after proper notice and hearings. This concept seems to be generally acceptable.

To date the state and local boards of soil and water conservation districts and the United States Agricultural Stabilization Conservation Service (ASCS) are the key organizations in non-point pollution control. Allocated funds have been disbursed by these agencies based on well defined guidelines. I wish to again emphasize that these programs are being administered locally, aided by technical and educational assistance and a degree of objection powers from both the Federal and State agencies. This cooperative program has had reasonable acceptance and success. Historically, over the past forty years, this has been only an agricultural program because there was a belief that the farmer was the greatest and only offender of sound land management practices. Presently, it is a well known fact, that the urban areas are equally in need of good land use and conservation practices.

Over many years it has been deemed essential and to be in the public interest for governments to expend large amounts of money for fish and game management, human waste treatment, highways, human services. (The list is endless and can include the costs of excursions to the Moon and Mars.) If we are in accord that all these are justifiable costs and programs in the general public interest can it not also be deemed in the public interest to allocate some matching Federal and State monies to meet the goals and purposes of our "208" planning.

In conclusion, what are some of my views on "208" planning that I deem worthy of consideration?

I am of the opinion local units of government working in harmony with Federal and State agencies can be the basis for meeting the ultimate goals of "208" planning. We have an established solid base to continue building upon and aggressively seek to improve on that which, out of necessity, was founded forty years ago. This base over a period of years has provided a degree of improvement of water quality and minimizing soil erosion and sedimentation. Voluntary landowner cooperation has been achieved by means of educational programs and monetary incentives. Let us build then on this established, proven base, and move forward with a greater degree of purpose and cooperation. This I believe to be more prudent than the creation of a new governmental agency and the possible resulting boondoggling.

For non-point discharges, controlling a broader statutary legislative framework for regulating land use and management practices in both the rural and urban areas may need to be made available at each level of government. I deem it desirable that such a legislative framework be based on discussions with those persons now actively working with the present ongoing program.

In our attempt to adequately document the remedial measures pertinent to the solution of "208" planning let us fully evaluate the assessment of probable costs as well as the apparent benefits any corrective measures create. In my observation of the EPA project study persently ongoing within our county it appears quite evident that the costs generated by any land management practices employed warrant monetary assistance for the cooperating landowners.

If for any reason the cooperating governments and agencies cannot complete our institutional and regulatory planning within the time constraints of the present law I would like to believe that the Federal Government would deem it prudent to extend the goal completion dates in the interest of reaching a plan reasonably acceptable to all parties effected. Such an approach would be comparable to those extensions that are presently allowed to industry, cities and villages in the abatement of point source pollution because federal and state funding has not been made immediately available.

The public today is much more vocal in its responses to issues and expects to play a more active role in government affairs. People are generally better informed and educated and are less willing to accept government mandates. The public now expects to be considered in any decision which affects them or their pocketbooks directly. We must by all means, create a greater understanding and help to develop a general awareness of the pollution problems associated with land use activities.

We must provide direct counsel and report to the public on specific problems and impacts on non-point source pollution as identified. We need to offer this information to those people or interest groups most likely to be affected.

We must totally assess the attitudes of individuals towards the adoption of environmental practices and also their perception of the problem and its resulting economic impact. This can be accomplished through full use of the news media, distribution of printed materials and organizing community forums to stimulate public cooperation and action. This will provide an opportunity for citizens to make a positive contribution to the design of remedial measures as well as administrative design.

To allow ample time for this process of dialogue and evaluation of any "208" program planning may be sufficient reason to give consideration to extending the law's deadline date for implementation. Any such delay may help to avoid resistance and confrontations amongst parties involved and be in the overall interest of achieving the reasonably acceptable major water quality goals of our "208" planning.

I have attempted to express some of the concerns of "208" planning as I view them from the vantage point of being privileged to serve as Chairman of the County Board, the Soil and Water Conservation District and the local Town Board, and yes, even as a farmer. I have cited some areas in which I believe we cannot afford to do less than our very best.

As citizens of our nation and communities I believe we face only the challenge of greater success although there will be many difficult decisions that must be made relative to non-point source pollution planning and the ultimate achievement of its goals. As leaders within the framework of federal, state or local units of government or agencies thereof, we should join in a pledge to create a greater degree of cooperation and understanding of practical possibilities. The necessity for development of the solutions to meet the goals of "208" law hopefully can be realized with a very minimum infringement of the rights and cherished freedoms of our citizens.

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION VIEW OF SECTION 208 PLANNING

by

Lyman F. Wible*

One of my colleagues advised me on this presentation. He said, "Don't tell people your troubles." I asked why not and he told me, "Half the people you tell don't care, and the other half are glad you're getting what's coming to you." Nevertheless, I would like to present a very brief summary of a regional planning commission view of areawide water quality planning under Section 208. Our agency was designated as the areawide water quality planning agency in December of 1974 and accordingly we will conclude our 208 project period in December of 1977. The Regional Planning Commission itself is composed of three representatives from each of the seven counties in and around the Milwaukee metropolitan area. It was organized in 1960 as a result of wide-ranging public discussions and debate initiated in 1948. It is especially interesting today to note the twelve years required to successtully determine the appropriate planning boundaries for the Southeastern Wisconsin Region, as compared to the time available for designation of 208 agencies.

Since 1960 the Commission has been involved in the conduct of comprehensive physical planning programs, which have included functional planning in the topics of land use, transportation, airports, housing, libraries, park and open spaces, water quality, air quality, floodland management, coastal zone management, and sandstone aquifer modeling, as well as clearinghouse and comprehensive planning functions. For this reason, we must consider the 208 product not as a plan as such, but rather as an element of a comprehensive physical plan for regional development. Thus, we may place a far more detailed importance on protection of environmental corridors or critical resources.

The areawide water quality planning program presents the Southeastern Wisconsin Regional Planning Commission with an opportunity to update, refine, and extend certain previous planning efforts of the Commission. The major previous activities related to water quality management include the development of comprehensive watershed plans for about 65 percent of the Region lying in the Root River Watershed, the Fox River Watershed, the Milwaukee River Watershed, and the Menomonee River Watershed. In addition, a regional sanitary sewerage system plan was prepared during the period from 1969 through 1972. It is useful to the Commission to update aspects of these planning programs to the same base year 1975, as well as to extend the water quality aspects of these programs to the other watersheds of the Region. In addition, the areawide water quality planning program offers an opportunity for the Commission to refine the technical work done in the previous planning efforts. New planning and analysis techniques which yield more accurate and precise answers are applied in the 208 program to further extend the planning horizon of previous planning efforts from 1990 -- which corresponds to all previously prepared plan years -- to the year 2000 which is, of course, the date identified as the plan design year for the 208 programs.

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*Lyman F. Wible, Areawide Water Quality Planning Project Coordinator, Southeast Wisconsin Regional Planning Commission

Specifically, the 208 program for southeastern Wisconsin is intended to provide a strategy for meeting and maintaining the water quality standards applicable to the lakes and streams of the Region from now to the year 2000. The Commission includes as major elements of the program six major phases. First is the formulation of objectives and standards; second is the conduct of inventories; third is the analysis and forecast phase; fourth is the design, test and evaluation of plan alternatives, fifth is the selection and adoption of a plan alternative and sixth is the plan implementation phase. Inventory data include base maps and aerial photography, surface water quality, groundwater data, implementation status of previous plans, surface water use data, review of concurrent planning efforts, socioeconomic base data, land use and community plans and zoning data, general natural resources and environmental data; existing and proposed sanitary sewerage systems; industrial wastewater discharges; storm sewer systems; agricultural animal feeding operations and cropping practices; sewage sludge handling and disposal data; the cost and effectiveness of techniques for wastewater management; public financial resources; land and wastewater management institutional structures; and existing legal mechanisms. The analysis and forecasts include the forecasts of growth and change in the population and economics of the Region, as well as the simulation of hydrologic, hydraulic and water quality phenomena. An identification of land uses and environmental constraints, wastewater conveyance needs and sewage sludge management needs, as well as analysis of waste management institutions are also included. Alternative plan elements for point source control, diffuse source control, sludge management and disposal, and water quality management agencies will be developed and evaluated for their environmental, economic, technical, legal, financial, and administrative impacts. Plan selection and adoption, as well as plan implementation are to be conducted in a manner similar to the traditional approaches used by regional planning agencies except that the additional approvals of the State and Federal agencies and the special need for the involvement of affected public will be given special consideration.

The 208 program presents a series of challenges to the Commission as a continuing comprehensive physical planning agency. Because there are other planning efforts currently underway or already accomplished by the Commission, there is a strong challenge to integrate the 208 program with current and past planning programs. Similarly, it is exceedingly challenging to provide a reasoned, objective and equitable integration of solutions to the point source pollution problems, with the solutions for diffuse sources of pollution. Perhaps most important, the program offers a similar opportunity to assess the importance of all major forces affecting water quality.

In light of the previous work accomplished by the Commission, it is highly challenging to conduct this program not only to provide useful information, but also to assure that planning as a social function does not suffer from overkill, or overfunding, or loss of credibility, due to a failure to meet the difficult time schedules and demands of the 208 program. It is critical that the 208 program be properly appreciated by local decision makers for what it is -- a complementing but not overlapping program.

The guidelines and requirements of the 208 program indicate that implementation is the critical measure of success of such a program. The Commission agrees that "the true test of the pudding is in the tasting," as they say, however, it is particularly difficult for a Commission which has been in existence for sixteen years, and involved in the development of numerous local projects and the implementation of many physical planning programs, to consider as realistic, some of the deadlines of the 208 effort. The specific point is this: The Commission has had numerous experiences in the development of sanitary sewerage systems on an areawide basis, and has found it typical that such projects take between five and eight years for their development. They take from five to eight years from the initial problem identification to the completion of local acceptance, funding, construction and institutional and management structures which assure effective and efficient operation and maintenance of such systems. Will the control of non-point sources take less time? Anything from a change of local elected administrations, to ecology concerns of local citizens, to the impacts of inflation on the local tax base and its capability to support a project, can slow or deter the completion of such important environmental control activities unless knowledgeable and seasoned technical personnel are and remain available to local decision makers during the project. Likewise, it is critical that these personnel have a consistent and continuing appreciation for -- and dedication to -- a sound and stable set of regional objectives. Many actors perform this role. We like to think we too are helpful in this regard. As an important example of this, it is useful to note the current tendency of nationwide research results to be applied to the Southeastern Wisconsin Region, where the Commission staff has consistently and publically taken the position that in southeastern Wisconsin, it is the lack of sewer extensions in conjunction with poor land use decisions, that causes urban sprawl -- not the availability of sewer extensions. A less seasoned staff might not have come to the same conclusion. Today, in our Region, essentially all of the sewered lots are sold -- even those which had been considered only marginally saleable, before the sewer extension ban on overloaded systems was recently imposed by the Wisconsin Department of Natural Resources. This is causing a trend in development onto septic tanks, for which the suitable soils in southeastern Wisconsin lie on the west side of the Region and about thirty miles distant from Milwaukee.

The technical conduct of the 208 program itself within such a short time period also presents difficulties. The hiring, training and retention of the number of qualified staff members needed; the constantly revised guidelines; the numerous guidance documents and publications which must be digested; the long hot summers of waiting for storm events; and the so-called "administrivia" are all distractions from the analysis and development of realistic alternatives for areawide water quality planning. The technical products which are the heart of the work effort may be momentarily forgotten in the scurry of administrative deadlines and activities. Finally, the technical work must result in usable answers, technical solutions, and realistic administrative structures. Against this backdrop, the conduct of the technical work, to result in plans which are supportable and will withstand the public scrutiny becomes exceedingly difficult.

But let us look on the positive side for a minute. Perhaps one of the most exciting aspects of this planning program has been the opportunity to interact with not only the agricultural technical personnel within the Region, but also some of the agriculatural practioners who have had a role in the work effort to date. In the development of the agricultural non-point source inventory, the Commission identified on low-flight aerial photographs, the land in agricultural use in the spring of 1975, when the aerial photos were taken. Working with the County Soil and Water Conservation Districts, the Agricultural Stabilization Conservation Service county staffs, the Soil Conservation Service district conservationists, and the University of Wisconsin-Extension service, the Commission staff attended a series of shirtsleeve work sessions, in which the delineated photos were further marked to identify the croplands; locations, the numbers, and types of animal feeding operations; and areas of particularly severe erosion. Through the assistance of the county staffs, the Commission was able to obtain the help of local township residents -- some were ASCS crop reporters, some were ASCS committeemen, some were field technicians, others were members of the Soil and Water Conservation District, some were drainage district members, and some were just people who did lots of farming. Others were retired ASCS personnel. Here is the testimonial Mr. Gilman hoped for -- because with such grass roots information, the Commission has been able to characterize the agricultural land use practices within southeastern Wisconsin to a degree of accuracy which could not be met with any amount of consultant services.

Similarly, with the assistance of the University of Wisconsin-Extension service, the Commission has undertaken a public involvement program which includes the identification of a series of public discussions at the county level. It was the feeling of both the Commission staff, and the assigned University of Wisconsin-Extension service specialist, that one logical unit for the development of detailed and localized public involvement efforts related to the areawide water quality planning program is in fact, the county unit. For this reason, it is anticipated that both urban and rural, point and non-point, long-term and short-term problems on water quality management will be addressed in a series of public forums at the county level. The Commission is optimistic that with this approach and the continuing support of the agencies discussed here -- as well as the support of the general purpose units of government and the public works directors and city engineers of the Region -- a successful and implementable areawide water quality planning program can be accomplished.

In summary, the Commission views 208 as an element of the comprehensive physical plan for this Region; as a complementing program to update, refine, and extend our previous water resources planning efforts, as a challenge to be met in integrating diverse planning programs; as dangerously brief in its plan development and implementation emphasis; and as an exciting experience in analyzing all of the factors affecting water quality and in developing the public support necessary to abate pollution.

It can be stated, by misquoting an old saying that, "The 208 Program offers incredible opportunities to a regional planning commission -- but they come in disguise as insoluble problems." In solving those problems we feel that highly useful information can be developed for sound water quality management decisions in southeastern Wisconsin.

Thank you.

SECTION 208 - A CONGRESSIONAL VIEW

By

J. Edward Roush *

The problem of non-point source pollution is one that we have been aware of for some time, although I can remember in the late 1960's when groups in Indiana representing agricultural interests testified with great feeling, at hearings on the state's water quality standards, that there was no such thing as agricultural pollution. I think the awareness of the problem of non-point source pollution was driven home in 1972 at the Maumee River Conference in Fort Wayne.

I arranged the Maumee River Conference specifically to talk about problems of the Maumee River which we had determined was polluted and for which it seemed to us, things were getting worse rather than better. At that conference, speaker after speaker pointed an accusing finger at agricultural as one of the prime contributors to the degradation of the Maumee.

Speakers said that municipal pollution was being controlled; that control of industrial pollution would soon be established; but that no one was doing anything about non-point pollution and particularly non-point pollution arising from agriculture.

It has always been a particular source of satisfaction to me that the agricultural community of Allen County, Indiana reacted not with hostility to that charge, but with a willingness to find out if there was in fact an environmental problem and at the same time to find out if there was something which could be done about it. The result of that willingness, the interest of the Region V office of the Environmental Protection Agency, the cooperation of the Department of Agriculture, of local government, and of Purdue University, was the Black Creek Project which you will be hearing about several times during this seminar.

It is worthy of note that the Black Creek Project was conceived and was under dicussion with the Environmental Protection Agency prior to the passage of PL 92-500 which contains Section 208. The subject of this two day meeting.

When congress was debating PL 92-500 there was, of course, concern over the municiple construction grants program. There was concern over stopping industrial pollution, but there were other concerns too. Congressmen from the Urban Megalopolis saw a need to impose uniform controls over all of the governmental units within a metropolitian area. They expressed

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*Member of Congress, 4th District Indiana the fear that a city doing a good job would be ineffective if other cities in the same area could not do a similarly good job. Congressmen from sea coast areas, particularly California, were concerned with the problems of salt water intrusion which their districts were experiencing. Congressmen from rural areas near large metropolitan areas were frightened of the prospects of land disposal of metropolitan sewage. Farm belt Congressmen were concerned that traditional exceptions for agricultural operations might not be placed in the final bill.

The Congressional attempt to resolve concerns and fears was area waste treatment planning. Both the Senate and the House bill called for area waste treatment plans. The house called for planning only in urban and industrial complexes, the senate called for total planning for the total geographic area of each state. The senate believed that plans should be developed by July 1, 1974. The house saw a slower process with planning initiated within two years of the adoption of the act. The senate said state agencies should use part of the construction grant funds for the planning. The house felt that a separate fund should be created. When the Conference Committee Report was issued the conferees, as we might expect, had taken part of the house bill, part of the senate bill, and put them together in what became section 208.

It is often popular to consider Section 208 a planning program only for non-point sources of pollution. The conference report which became Public Law 92-500 went considerably beyond that. The plan called for in Section 208 requires:

A. The identification of treatment works necessary to meet the needs over a 20 year period.
B. The establishment of priorities.
C. The establishment of a regulatory program for industry.
D. The identification of agencies necessary to construct, operate and maintain all facilities.
E. The identification of measures including the time necessary and the costs of carrying this out.
F. A process to identify and control agricultural and sylvicultural related non-point sources of pollution.
G. A process to identify mine related sources of pollution.
H. A process to identify construction activity which is a source of pollution.
I. A process to identify salt water intrusion and decide how to control that.
J. A process to control the final disposition of all residual waste which could effect water quality.
K. A process to control the disposal of pollutants on land or in sub-surface excavations to protect water quality.

In other words Section 208 covers the entire plan for a state and there is a very real basis for labeling this section as the "heart" of Public Law 92-500.

It is fair to say, that over the past five years, the Environmental Protection Agency has concentrated on other sections of the act. As a result that National Commission on Water Quality has indicated that the contributions of pollutants from non-point sources may prevent the achievement of the water quality goals of the act and may even overwhelm the improvements resulting from the control of point sources.

Some estimates have been made that 208 planning will not begin to address, area wide waste treatment problems, until after 1977. By that time if the 1977 standards for point sources have been met by municipalities and industries, non-point source pollution would be expected to account for 145 million pounds which is 95% of the total of suspended solids per day; 28.3 million pounds - 79% of the nitrogen per day; 1.9 million pounds or 53% of the phosphorus per day and over 98% of the national loadings for both fecal and total coliform counts.

While Environmental Protection Agency has been dealing with the Construction Grant Program and the discharge permit program, it has consistently fallen behind in the implementation of Section 208, specifically, E.P.A. has:

A. Failed to meet the statutory deadlines required by the Federal Water Pollution Control Act 92-500.
B. Promulgated regulations which were subsequently found to be in violation by federal court.
C. Impounded 137 million dollars in contract authority which had been ear-marked by Congress to provide regional planning bodies with 100 start-up funding for 208 planning.

With the adoption of 92-500, congress anticipated that 208 planning would be under way and would impact all water quality decisions by mid 1975.

Over the past year, to year and a half, the priority of implementing Section 208 has increased. In the last fiscal year 135 areas were approved and additional 23 areas were designated by governors or by local authorities where governors failed to act.

The reluctance of federal agencies to deal with section 208, particularly the problems relating to non-point source pollution is certainly understandable. Solutions to the problems of non-point source pollution make the problems which surrounded the implementation of the municiple construction grants program and the implementation of the discharge permit program seem simple. Plans to deal with non-point source pollution will not be able to point fingers at single heavy sources of pollutants and require immediate action by well identified groups or individuals.

The cost of dealing with non-point sources of pollution will be great whether that cost is born by the federal government, by state and local governments, by individuals or by some combination. The municipal construction grants program has involved the largest public works program in the history of the nation. It is fair to predict that expenditures for control of non-point source pollution will have to equal or exceed that amount if a real impact on the problem is to be achieved.

I remain convinced, however, that there is a cause for optimism and a chance for success. I point again to the reaction of the agricultural community in Allen County, Indiana when after the adoption of the Maumee Conference Report and after an accusing finger had been pointed at them, they did not raise cries of anguish and vow to fight those persons who had made the accusations. They instead vowed to band together, discover what the problem was, and find out how they could help solve it. I believe this is a reaction that we can expect from farmers.

I believe that the Black Creek Project has demonstrated this. I believe that the kind of federal, state, and local cooperation invisioned in Section 208 can accomplish wonders and more over I believe that it will.

THE WASHINGTON COUNTY PROJECT - AN OVERVIEW

by

T. C. Daniel*

The primary objective of the Washington County Project is to demonstrate the effectiveness of land treatment measures in improving water quality, and to devise the necessary institutional arrangements required for the preparation, acceptance and implementation of a sediment control ordinance or other management program applicable to incorporated and unincorporated areas on a county-wide basis.

The conceptualization of the project, the participation and involvement of appropriate interest groups and the development of project objectives is reviewed. Each objective is discussed with emphasis on strategies for implementation and accomplishments to date.

Development of the Washington County Project began in April of 1973 as a result of the Governor's Conference on Sediment and Erosion Control held at Madison, Wisconsin (1). Preliminary meetings followed, identifying those organizations and agencies concerned with nonpoint pollution, particularly sediment. During the two year period, the list of participants in the project was expanded to include representatives of federal, state and local agencies, academic institutions, elected officials and appropriate interest groups. An executive committee representing the participants was created and charged with the responsibility of reviewing the status of the nonpoint pollution problem, identifying the major problems needing investigation, developing project objectives, and providing a mechanism for project implementation (Table 1). For detail concerning the organization, roles and responsibilities of the various committees involved in the project the reader is referred to the Washington County Project Work Plan (2).

The remainder of this report will provide information on the background of the project, project objectives, approaches to achieving those objectives, and project accomplishments to date.

BACKGROUND OF THE WASHINGTON COUNTY PROJECT

The Federal Water Pollution Control Act-Amendments of 1972 (P.L. 92-500) addresses the problem of protecting and improving the quality of the nation's lakes and streams. The legislation is specific with respect to the types of pollution to be investigated, the mechanisms and time frame required and the agency(ies) having primary responsibility for accomplishing the control aspects of the law. In the past, the US-EPA has directed efforts towards the control of point sources of pollution and the development, revision and updating of guidelines for controlling the quality of effluent discharged from industry, municipal treatment plants and feedlots are being revised and updated to reflect advances in treatment technology. Additionally, the US-EPA is focusing attention on nonpoint or diffuse sources of pollution such as agricultural and urban runoff. Because of their diffuse character, these pollutional sources are more difficult to quantify and define. Undoubtedly, controlling these pollutional sources is complicated by the interrelated complexities and inherent variability in the systems involved and by the lack of background information required to define the problem. However, control of nonpoint sources is of great importance for maintaining the quality of surface waters and management methodology for minimizing their discharge must be developed.

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Sediment transport and deposition is a classic example of pollution arising from a diffuse source. Nationally, sediment is by volume the single largest pollutant of the nation's surface waters. Aside from the objection to sediment from an aesthetic standpoint, deposition of sediment in surface waters can cause a degradation in water quality resulting from increases in suspended and bed loads, total dissolved solids and oxygen demand. Eutrophying and other components of the eroded material, such as readily available ortho-phosphate, soluble nitrogen and pesticides, etc., are also released as a result of the interaction between eroded soil particles and surface waters. Annually, dredging costs to keep the nation's streams and harbors open are conservatively estimated at $300 million.

Table 1. Organizations and Agencies Involved in the Development of the Project

Abbreviations	Organizations and Agencies
NACD	National Association of Conservation Districts
SEWRPC	Southeastern Wisconsin Regional Planning Commission
USDA-ASCS	United States Department of Agriculture - Agricultural Stabilization and Conservation Service
USDA-SCS	United States Department of Agriculture - Soil Conservation Service
US-EPA	United States - Environmental Protection Agency
USGS	United States Geological Survey
UWEX	University of Wisconsin-Extension
UW-MAD	University of Wisconsin-Madison
UW-SNR	University of Wisconsin - School of Natural Resources
UW-Soil Sci	University of Wisconsin - Department of Soil Science
UW-WRC	University of Wisconsin - Water Resources Center
WCSWCD	Washington County Soil and Water Conservation District
WDNR	Wisconsin Department of Natural Resources
WGNHS	Wisconsin Geological and Natural History Survey
WSBSWCD	Wisconsin State Board of Soil and Water Conservation Districts

Although erosion and subsequent sedimentation is a natural geological process which cannot be eliminated completely, man's activities can, and have, greatly accelerated the process. The rates of soil loss are directly related to types of land use. Sediment, with its deleterious effect on water quality, has been identified as the major pollution problem in seven of the 17 chapters describing the effect of different land use categories cataloged as potential sources of loading to the Great Lakes by a Reference Group of the U.S.-Canada International Joint Commission (3). This comprehensive review of land use in relation to pollutional loading into the surface waters of the Great Lakes clearly identifies sediment as a major pollutant and calls for new and innovative programs for its control and prevention.

The primary source of sediments polluting surface waters is agricultural and other rural lands lacking adequate conservation practices. However, a second major source of sediment is land undergoing changing use patterns as exemplified by areas of rapid urbanization (construction sites). This source comprises a major hazard because it is largely unabated and conservation practices are normally not applied during construction. Rates of erosion from urbanizing areas may exceed those from agricultural lands by factors from 100:1 to 200:1. Sediment loading into surface waters will continue to increase with time due to the increased demand for agricultural production which involves both more intensive agriculture and the cultivation of formerly idle land, and to continual urbanization and the development of previously rural lands. The land being newly brought into agricultural production is likely to be critical when evaluated in terms of its potential erosional hazard either because of the slope or shallowness of the soil.

Historically, the problem of soil loss has been viewed strictly as a rural problem controlled only for the economic benefit of the landowners. Presently, and to a greater degree in the future, deterioration in water quality arising from sediment deposition either from rural or urban areas must be viewed in light of the general public's right and desire for high quality surface water and included in this evaluation must be the downstream cost and effect of sediment deposition.

Prior investigations and experience by agencies such as the USDA-SCS have led to the development of an erosion control technology which if fully implemented will dramatically reduce soil loss from unprotected cropland and construction site areas. The major obstacle has been an inability to develop and implement programs which provide a uniformly high degree of land application of conservation practices. Prior experience has shown that the voluntary and incentive mechanisms have been successful to a point; however, these programs do not result in a uniformly high degree of implementation of land practices. Erosion can be controlled--the problem is the development of new and innovative management programs to correct the inadequacies of a strictly voluntary-incentive program.

Solving the basic problems of implementation of conservation practices necessitates investigating the social, economic, legal, and political aspects of the issue as well as the technical components. Answers to these questions can only be provided by multiagency and interdisciplinary programs devoted to problem-oriented research and demonstration. It is only through this mechanism that a forum of exchange between those affected by management programs and the agencies (federal, state, local) required to develop and administer such programs that realistic guidelines and methods of implementation can be developed.

OBJECTIVES

As a result of input from the participants identified in Table 1 the overall objective of the program is to demonstrate the effectiveness of land treatment measures in improving water quality, and to devise the necessary institutional arrangements required for the preparation, acceptance and implementation of a sediment control ordinance or other management program applicable to incorporated and unincorporated areas on a county-wide basis. Specific objectives deemed necessary for the successful attainment of the overall objectives are:

1. Demonstrate through a monitoring program the effectiveness of sediment and erosion control techniques for improving water quality.

2. Develop a sediment control ordinance or other management mechanisms acceptable to landowners and the several governmental authorities responsible for implementing such measures and determine the combination(s) of institutional arrangements in the form of laws and intergovernmental relationships involving federal, state, county, and municipal governments required for implementing management programs in incorporated and unincorporated areas on a county-wide basis.

3. Develop a model of the personnel required and the technical and financial assistance needed to implement a sediment control program.

4. Develop and systemize the educational and information dissemination effort to the general public and appropriate user groups required for implementing a sediment control program.

5. Provide an evaluation of the feasibility of implementing management programs for sediment and erosion control in the Great Lakes Basin States and other areas where applicable.

PROCEDURES FOR IMPLEMENTATION OF OBJECTIVES

Each of the objectives will be discussed individually with respect to mechanisms and procedures identified for their implementation. The purpose of this document is to provide a brief summary of major project activities. For more detailed information, the reader is referred to the Washington County Project Work Plan (2).

Demonstrating Improvement in Water Quality

The area of water quality vs. land use and its associated runoff necessitated clarifications especially in light of potential regulatory programs. Two watersheds, one agricultural (Kewaskum) and the other rapidly urbanizing (Germantown) were selected in Washington County, Wisconsin (Figure 1). The Kewaskum Watershed is devoted primarily to a dairying type of agricultural enterprise. A dairy farming area was selected because dairying is the dominant type of agriculture in the Great Lakes Basin (4). The Germantown watershed has been identified as the areas in Washington County scheduled for rapid development and subsequent construction activity (5). This rapid development is a result of population pressure from the nearby Milwaukee metropolitan area. Intensive water quality monitoring activity is scheduled for the two watersheds and information will be developed on a total loading basis for selected parameters. Background information will be developed concerning runoff under present land use conditions with subsequent information collected as a result of the implementation of intensive conservation practices. Information provided from this activity will be utilized in various aspects of developing a management program, i.e., cost benefit, background levels of pollutants, effectiveness of conservation practices on water quality and sediment delivery ratio.

Development of a Planning and Management Program for Sediment Control

Efforts in this area focused on identifying and integrating the expertise required to work on the legal, social, political, and economic aspects of the project. Problem areas will be handled by individuals whose research interests are devoted to the solution of problems of a practical, people-oriented nature. Definition of objectives and mechanisms of accomplishment have been evaluated in each discipline for the respective graduate research assistants and biweekly meetings are in progress to insure coordination. Specific analysis of existing state and local statutory authorities have been initiated. An examination of existing federal, state and local institutional arrangements and their potentials for implementing sediment control programs also has been initiated.

Personnel, Technical and Financial Requirements

Any management program developed will require clear identification of staff needs to implement and administer such programs. The importance of this component cannot be overlooked for, in part, it will determine the economic acceptability of the different alternatives and become increasingly more critical when the results are projected on a regional basis. The amount or level of personnel required at the local, state or regional level is less known than the type of personnel required. These activities will be accomplished in concert and concomitantly with objective 2.

Education and Information Program

Specific local audiences have been identified and informational brochures and slide sets are in various stages of development. Numerous visual aids, namely slides and film, showing the local leaders and monitoring site installations have been collected. A slide set for use in

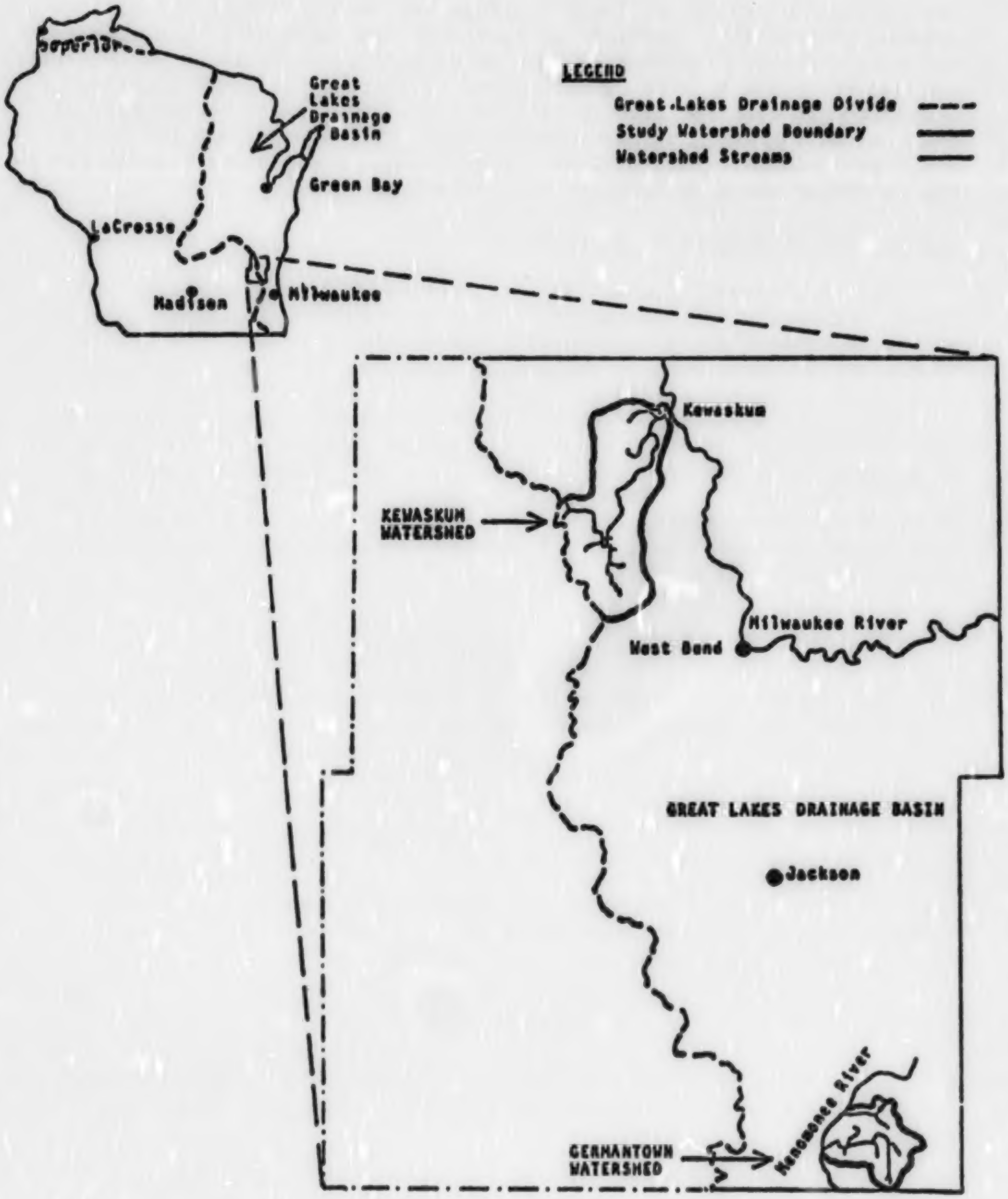
Superior
Great Lakes Drainage Basin
Green Bay
LaCrosse
Madison
Milwaukee
LEGEND
Great Lakes Drainage Divide
Study Watershed Boundary
Watershed Streams
Kewaskum
KEWASKUM WATERSHED
Milwaukee River
West Bend
GREAT LAKES DRAINAGE BASIN
Jackson
Menomonee River
GERMANTOWN WATERSHED

Figure 1. Map of Washington County, Wisconsin, Showing Its Geographical Location and Selected Project Sites in the Great Lakes Drainage Basin.

describing the project at local meetings has been developed and will be updated continually. Several informational brochures have been identified which will provide information concerning sediment effects on water quality and how the project is being structured to address the total question of nonpoint pollution for distribution to state, regional (interstate) and national audiences. The mechanism of developing appropriate brochures and visual aid materials will be a coordinated effort among several disciplines within the University of Wisconsin-Extension.

Application of Results to Other Areas

The development of a sediment control management plan for Washington County will serve as a demonstration of technical and institutional mechanisms for conducting a county-wide, rural-urban program. The demonstration must, however, achieve the goal of being implementable on a much broader geographic scale, i.e., statewide, regional or perhaps, even national. It is fully understood that this demonstration can only serve as a prototype since other areas will have to develop programs taking into account their own unique political, legal and economic constraints. However, when utilizing Washington County as a demonstration site, part of the evaluation of the alternatives must include those programs which institutionally have the inherent ability to be projected to state, regional and national scope.

SUMMARY AND PRESENT STATUS

The project was funded in June 1975 with the Wisconsin State Board of Soil and Water Conservation Districts as the grantee and will continue through December 1978. Initially, most of the activity centered around accumulating project and support staff. Interdisciplinary groups have been established and coordination of activity initiated. Monitoring site installation is completed. Many elected and public officials in Washington County have been active in all phases of the project and have taken the leadership role at the local level. Accomplishment of the objectives will be performed in concert with each other, however, little substantive activity is expected on objective 3 or 5 until the middle stages of the program.

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WESTERN LAKE SUPERIOR BASIN
EROSION-SEDIMENT CONTROL PROJECT
(RED CLAY PROJECT)

by

Stephen C. Andrews

Project Director

The Red Clay Project is a research and demonstration project funded by the U.S. Environmental Protection Agency under Section 108 of the 1972 Amendments to the Federal Water Quality Act (PL92-500). Section 108 provides funds for projects in the Great Lakes Basin for the collection of data to be used as a basis for planning and implementing non-point source pollution control programs to help improve water quality.

The red clay soils in the Western Lake Superior basin were formed by lake deposits which have subsequently become exposed by the receeding lake and geologic uplift and are now part of the land mass forming the Lake Superior basin. In geological terms, this makes these soils young, unstable and susceptable to a relatively high rate of erosion. The process of erosion and the deposition of the resulting sediment in lakes are very natural processes. However, these processes are accelerated by man's activities and the results can be very detrimental and costly. Through a combination of these natural events and inadequate planning and management on the part of man, valuable agricultural land is lost, shore front property is eroded away, sediment pollutes the waters, carries other pollutants with it and fills economically important harbors.

Over the years there have been considerable numbers of studies done on the problems of red clay erosion. The Red Clay Project came into existence as another part of the ongoing research. It will be making use of past research but should not be viewed as the end result of all the previous studies. The Project did not arise out of other studies, but grew independently to examine problems which others did not and to add to the storehouse of information upon which comprehensive, long-term control programs can be built.

NEMADJI BASIN

Detailed soil surveys have been completed on 5,530 acres and 7,760 acres of reconnaissance soil surveys were made during the past year. Some winter soil survey work was completed on large organic soil areas with the aid of snowmobiles.

Detailed soil profile descriptions were written and correlation samples were gathered for 7 series. In addition, 4 profile samples for detailed laboratory analysis were taken. Soil survey field sheets for completed areas and soil interpretations are available from the Soil Conservation Service Office in Superior upon request.

The Critical Area Treatment plans for roadside erosion control throughout the Nemadji Basin have been completed. These plans call for erosion control on 34.7 acres of roadsides in the Town of Summit, Town of Superior and City of Superior. Twenty-seven areas have been identified as needing structural measures to control the erosion.

In addition, two sites have been selected to demonstrate innovative techniques of roadside erosion control. One site is on clayey soils and one site is on sandy soils. On these study sites various combinations of seeding mixtures and mulching techniques will be demonstrated in plots 40' wide to provide for comparison.

LITTLE BALSAM CREEK STUDY AREA

Floodwater Retarding Structures

Floodwater retarding structures are installed to provide for temporary storage and controlled release of floodwater during periods of peak flow. These structures also trap sediment. It is intended that the controlled release of floodwater will lower the runoff peaks and reduce damage to the streambanks downstream from the structure sites. The effect of trapping sediment and reducing streambank erosion will improve water quality in the Little Balsam watershed.

Several alternative sites were considered for this portion of the overall program:

1. Section 16, on the main tributary, in the upper part of the watershed.

2. West tributary in Sec. 34 in the lower part of the watershed. This will control flow on an intermittent stream.

3. East tributary in Sec. 34 in the lower part of the watershed. This will control flow on an intermittent stream.

4. Section 3, on the main channel, in the lower part of the watershed.

After field evaluation and hydrologic routings were completed, it was decided that adequate floodwater retarding structure sites do not exist in the basin. All sites evaluated lacked the needed storage capacity to accomplish program objectives. Therefore it is recommended that floodwater retarding structures be deleted from the proposed plan of work.

Foxlord Road and Soo Line Railroad Crossings

Little Balsam Creek flows through a concrete culvert beneath the Soo Line Railroad tracks. There is a streambank failure on the north bank of the railroad fill. Surface water is cutting a channel on both sides of the creek where the culvert, railroad fill and streambank meet.

Replacement of eroded fill, stabilization of the failing bank and proper disposal of surface runoff water will improve water quality in Little Balsam Creek.

Little Balsam Creek flows through a concrete culvert under Foxlord Road approximately .1 mile west of Patzau. Roadfill stability is poor because the side slopes are steep and poorly vegetated. Roadside runoff has eroded gullies adjacent to the roadway where the roadfill meets the steep ravine bank. Large amounts of fill are deposited by mass wasting of the roadfill and roadside gully erosion. Hazardous travel conditions are created when the roadfill slopes fail.

Detailed engineering field surveys and a topographic map have been completed for both crossings. Several construction alternatives have been developed for both sites.

Streambank Slip and Slide Control

Large amounts of sediment are contributed to Little Balsam Creek by mass wasting of the streambank. Structural measures will be installed to protect the toe of the slope and stabilize the streambank.

Streambank slip and slide stabilization will be demonstrated on 5 slides identified in Section 34, North of the Burlington Northern Railroad tracks.

Several alternative methods of stabilization will be considered for installation along the main channel of the Little Balsam Creek:

1. Groins in the stream to deflect current from toe of slope.

2. Rip-rap of the streambank.

3. Cribbing of the toe of the slope.

4. Snag removal from stream channel to redirect stream current.

5. Gabions.

6. Subsurface drainage to eliminate seepage areas on streambanks.

7. Diversion above slope to divert excess surface water from the streambank.

In addition, several vegetative alternatives that could be used alone or in conjunction with structural measures, were considered:

1. Shaping and seeding entire area.

2. Shaping and application of seed to horizontal bands.

3. Tree removal on slope to encourage growth of dense ground cover.

Four resource conservation plans (LTA) have been completed. Installation of fencing for livestock exclusion and a livestock watering facility started this spring. Resource conservation planning is in the process with three additional landowners in the study area.

The most common practices being requested by landowners include fencing for livestock exclusion from streams, pasture and hayland planting and/or management, livestock watering facilities, and livestock stream crossings. Manure storage facilities, grassed waterways and surface drainage have also been requested. Each farm unit will be using its soil resources within the allowable soil loss limits upon installation of all planned practices.

Inventories and evaluations are being completed for those landowners who are presently using the land within allowable soil loss limits and/or for those who do not want or are unable to cooperate with the program at this time. The average annual soil loss from sheet erosion measured in the inventories and evaluations completed to date is less than 2 tons per acre.

PINE CREEK (FISH CREEK BASIN) STUDY AREA

Modification of a stream channel near the junction of Pine and Fish Creeks is proposed in the workplan. This proposal is intended to demonstrate the effect of channel modification on streambank stabilization and improved water quality.

Detailed engineering field survey is completed for the channel modification site. A topographic map is available for the area. Several channel modification alternatives have been discussed, but no final decisions have been reached to date.

Resource conservation plans (LTA) have been developed and approved for fourteen landowners in the Pine Creek study area. Surface drainage, grassed waterways and diversions have been installed. Work is progressing on the installation of fences for livestock exclusion.

Resource conservation plans are in the process of development for additional landowners. Landowners have requested assistance with fencing for livestock exclusion, livestock watering facilities, livestock stream crossings, grassed waterways, surface drainage and manure storage facilities. Each farm unit will be using its soil resources within the allowable soil loss limits upon installation of all planned practices.

Soil survey is completed on 47,700 acres of the Fish Creek study area. Copies of individual field sheets and soil interpretations, may be obtained from the U.S. Soil Conservation Service Office in Ashland, Wisconsin.

SPOON CREEK (ORONTO-PARKER BASIN) STUDY AREA

The site for the proposed debris basin has been moved from Oronto Creek to Spoon Creek. This change resulted from concerns voiced over fish migration in Oronto Creek and detailed field evaluation of the structure site. The Spoon Creek site will eliminate these concerns.

The Universal Soil Loss Equation has been applied to all the land within the Spoon Creek study area. The average annual soil loss from sheet erosion is .59 tons per acre. Approximately 40% of the material removed by sheet erosion reaches the stream channel.

Detailed field engineering survey is completed for the Spoon Creek debris basin. Field notes have been plotted and a topographic map of the structure site and floodpool is available. Several alternatives have been proposed.

The debris basin will be designed for maximum sediment accumulation. Approximately 930 tons per year will be delivered to the proposed structure site from sheet erosion, streambank erosion and gully erosion. This sediment accumulation will occupy 31 acre feet at the end of 50 years.

The detailed soil survey of Spoon Creek basin is complete. Copies of field sheets and soil interpretations may be obtained from the U.S. Soil Conservation Service Office in Ashland, Wisconsin.

SKUNK CREEK STUDY AREA

Engineering plans and specifications have been completed and approved for the Elim Creek floodwater retention structure.

The floodwater retarding structure has been advertised for construction. The Sponsors are presently selecting the best qualified bidder. The contract will have a performance time of 80 calendar days.

The soil mechanics analysis of the Elim Creek structure site material indicates that the foundation is pre-consolidated. Shear strength analysis of the foundations material, along with test fill studies, were used to complete the slope stability analysis. With a 40 foot fill height the following slope requirements are planned:

1. Downstream slope - 3 to 1 slope with a 10 foot wide stability berm at 1/3 the fill height.

2. Upstream slope - 3 to 1 slope above the permanent pool; a foot wide berm at pool level; 3.5 to 1 slope below the pool level.

A complete soil mechanics report is available from the Soil Conservation Service, Duluth, Minnesota upon request.

The principal spillway will be a 24-inch diameter reinforced concrete pipe with pour concrete riser. The pool will be a maximum of 18 feet deep and will provide for 50-year sediment accumulation and livestock water supply. The slow drawdown pool between will be controlled by an orifice that will provide temporary storage for 1 inch of watershed runoff.

A second floodwater retarding structure is proposed on Skunk Creek on the Hanson property. Field engineering surveys and geologic investigations have been completed for the Hanson site. The addition of the Hanson structure will reduce flood peaks by 40 percent in Skunk Creek below the junction with Elim Creek. Flood peaks above the junction with Elim Creek will be reduced by 50 to 60 percent.

Construction plans are nearly complete for about one-half of slide stabilization work to be done along County Road 103, and will be titled Red Clay Erosion Control, Part I. The main item of work is building a buttress against the slide just north of the bridge. This will be accomplished by diverting the stream away from the slide and raising the stream bed about 11 feet. A 48 inch diameter culvert will pass 150 cfs (Q_2) at present stream gradient and a 12 foot drop structure will stabilize the downstream end of the raised channel. Considerable rip-rap and some slope drainage compliments this structure.

Another item is a rock gabion wingwall extension on the northwest corner of the bridge. Also about 4,000 feet of tile drain is included in the upland south and east of the bridge and along the cut slope sides of County Road 103 both north and south of the bridge. About 1,000 feet of cut slope will be shaped and reseeded. The resulting excavation will be used to build the buttress referred to earlier.

Additional stabilization work is planned along County Road 103 and upstream on Elim Creek and Skunk Creek. Construction plans on this will be completed this fall and winter for next year's construction. Alternatives considered include:

1. Logs placed longitudinally on the bank and fastened together to protect the banks from scouring. Some of the logs will be made of concrete to insure durability and antiflotation. This will be done with minimum construction disturbance to the natural landscape. Total length of protection would be 400 - 500 feet. Estimated cost is $30 per foot.

2. A bin wall type structure that will be back filled and bin filled with pit run gravel. This protection is planned for 250 feet on one side at an estimated cost of $200 per foot.

3. Tile drainage is planned immediately above the eroding slope. Total length of tile would be about 2,000 feet in the upland. The depth will be determined by soil drilling to find the water producing strata. Use of plant material, "biological pumps", is also planned for this eroding slope. Final selection of plants to use hasn't been completed. Estimated cost of tile installation is $4,000.

Resource Conservation plans (LTA) have been developed and approved for sixteen landowners in the Skunk Creek study area. Implementation of planned practices started this spring and will continue until all planned practices are applied. All implementation is scheduled for completion prior to July 1, 1978. Fencing for livestock exclusion, and hayland planting practices have been completed to date.

Resource Conservation Plans are in the process of development for several additional landowners. Landowners have requested assistance with livestock stream crossings, livestock watering facilities, grassed waterways, surface drainage and sediment traps.

Woodland management plans are being developed by the Minnesota Department of Natural Resources Division of Land and Forestry. Eight landowners requested forestry planning assistance at an informational meeting held this winter. Several of the requested plans have been completed and delivered to the landowners.

The use of vegetation to remove excess soil moisture, will be demonstrated along Highway 103. A draft copy of the plan for this proposal will be completed this fall.

ASHLAND SHORELINE STUDY AREA

Ashland County was selected to demonstrate shoreline protective devices including rip-raping and selected configurations of Longard tubes.

Early surveys of four potential sites indicated that the Indian Cemetery site on Madeline Island would be an appropriate location for rip-raping. In addition to providing demonstration capability, it also will protect a valuable archeological resource. Madigan beach, about 15 miles east of the City of Ashland was chosen for the Longard tube research and demonstration area. This beach has many high erodible clay bluffs which need stabilization. The primary problem is one of waves eating out the toe of these slopes. It is felt that Longard tubes in seawall and grain configurations may be useful in stabilizing the bluffs.

At the time of this report, permits have been secured from the Wisconsin Department of Natural Resources and the Army Corps of Engineers. It is expected that construction will commence early in the spring of 1977.

RESEARCH

All research is on schedule. Several reports of interest have been included in the proceedings.

MONITORING

All proposed water quality monitoring stations have been installed and are operating.

BLACK CREEK PROJECT OVERVIEW

by

Ellis McFadden[1]

The Black Creek Sediment Control Study, an Environmental Protection Agency funded project to determine the environmental impact of land use on water quality is finishing its fourth year of activities. The project, which is directed by the Allen County Soil & Water Conservation District, is an attempt to determine the role that agricultural pollutants play in the degradation of water quality in the Maumee River Basin and ultimately in Lake Erie.

The Black Creek project was designed and developed by a consortium of the Environmental Protection Agency, the Soil Conservation Service of the United States Department of Agriculture, Purdue University, and the Allen County District. It is a response to allegations, first brought to the attention of Allen County residents at a conference on the future of the Maumee River sponsored by Representative J. Edward Roush in January of 1972.

At the conference, sediments and related pollutants were named as major contributors to the degradation of water quality in Lake Erie. It was further suggested that agricultural operations significantly increased the amount of sediment and sediment related pollutants.

The Black Creek Sediment Study, funded by a grant of nearly two million dollars is an attempt to discover the role that agricultural operations play in the pollution of the Maumee River and how that role can be diminished through the application of significant land treatment practices.

The project represents a multi-agency, multi-discipline approach to the total problem of non-point source pollution. It involves demonstration, through a problem of accelerated land treatment with the assistance of the Soil Conservation Service, applied research by Purdue University, administration by the Allen County Soil & Water Conservation District, and cooperation from a variety of state, federal and local agencies, as well as the private landowners in the study area.

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[1] Chairman of the Allen County Soil & Water Conservation District Board of Supervisors in charge of administering the Section 108 grant from the U.S. Environmental Protection Agency for the Black Creek Study.

THE CHALLENGE OF 208 PLANNING

By

James B. Morrison *

These remarks are directed to the non-point aspects of section 208, particularly as they relate to agricultural pollution and the requirement that section 208 plans address the needs of the agricultural communities. They are made from the perspective of a person who has functioned as a close observer of the Black Creek Project, and they deal with with what might be described as "consciousness raising".

I direct your attention to the reports on Lake Erie Water Quality issued in the late 1960s, and particularly to the statements made at that time about the Maumee River Basin. The consensus was that although the Maumee contributed large amounts of silt to Lake Erie, this could not really be considered a source of water quality degradation.

By 1972, enforcement officers at the Environmental Protection Agency were saying that the Maumee River was a major contributor to the pollution of Lake Erie because of the silt load and the related nutrients which were carried with it. It was fairly common to hear the prediction that by simply applying standard techniques of soil conservation, the load of silt and related pollutants could be cut in half.

Currently, as Section 208 planning begins to be implemented, we have reached the position of believing that soil erosion is a major part of the non-point problem, but we are not as convinced as we once were that the application of standard techniques are going to easily solve the problem.

This is the kind of consciousness raising that relates to the environmental movement in general -- first we have a belief that there is no serious problem, we progress to a belief that there is a problem, but feel confident that the solution is relatively simple, finally we understand that the problem we have is a complex one and is not subject to answers that are immediately obvious.

You are going to hear many people say that the problem of agricultural non-point pollution is different than other problems we face in obtaining water quality. This is true, but not true for the reasons that are frequently cited. In farming, planners and regulators are dealing with a basic resource -- food - as opposed to a manufacturing operation or finished product. Tinkering with agricultural production has an impact not only on the financial condition of individual farmers and the cost of food at the super market. It has an impact on the availability of a basic resource.

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*Field Representative for Congressman Roush

This dual impact can be considered in relationship to the profit potential of individual farms, and the resource availability of food and fiber. Let's look at some possible combinations.

1. No Reduction In Profits - No Reduction In Productivity.

Soil conservation, as it has been conceived by the Soil Conservation Service, has been aimed at maintaining soil loss below the amount which can be regenerated on the land. Many of the traditional practices advocated by SCS will in fact increase productivity and can increase profits by the simplification of operation, the need for reduced supplies of fertilizer, etc. These same practices can have a beneficial effect on water quality, although it is not certain that they can meet the objectives of control of non-point source agricultural pollution.

2. No Reduction In Profits -- Reduction in Productivity

Certain practices, of which certain applications of minimum tillage are a good example, can result in an increase in profits, even though there is a reduction in yield. By this I do not mean to imply that minimum tillage necessarily results in a reduction in yield, but in some cases it can, and profits can be maintained because of lower expense incurred in the reduced number of farming operations. In this case, there is no profit reduction, but there is a reduction in the basic food resource availability.

3. Reduction In Profits -- No Reduction In Productivity

The installation of practices which require heavy capital outlay such as elaborate systems of terraces or the installation of sediment basis on non-productive land at the base of a watershed may have no effect on the productivity of cropland in the upstream area. They may, however, involve capital costs so large that the costs cannot be recovered over the normal farming life of an individual landowner. His profits are reduced (or eliminated) but productivity is maintained.

4. Reduction In Profits -- Reduction in Productivity

Finally there is the situation in which measures required -- perhaps removing land in critial areas from production, imposing a rotation with more years of grass crops, or requiring the construction of a sediment basin on land which would otherwise be productive, results in both a reduction in profits and a reduction in productivity.

The challenge to water quality planners is to recognize what combination of these impacts pertain. In those situations where there can be demonstrated to be no-long terms decrease in profit potential, education and regulation has a good chance of success in achieving water quality goals.

Where there can be expected to be a reduction in profit potential, farmers are going to expect incentive payments as a condition for accepting controls. This does not necessarily mean that they will receive them or that they should receive them, but it is certain that they will expect them.

Finally, in dealing with the question of reduced producitivy, a decision must be made about what the prime need is. It is possible that the imposition of controls in any individual region or state will have no significant national impact. However, if all regions and all states imposed regulations and controls that led to a reduction in food production, there would be an important impact.

More to the point, I have heard at least one 208 planners offer the opinion that regulations have to be uniform across a state; because it would be unfair to farmers in erosion prone areas did not have to meet. That is a politically satisfying proposition, but it may be a silly point of view when we consider the potential impact of regulations such as these on basic production of food resources.

Congress, in writing section 208, inserted four words in mandating planning for control of agricultural pollution. Those words were "to the extent feasible".

It may very well turn out that the challenge of 208 planning as it relates to agricultural non-point pollution is to define what "feasible" means in relation to the water quality goals we are striving for.

Public Participation in Land Use Planning and Management

by

F. W. Madison*

At the outset, it should be pointed out that the Washington County Project which is funded under Section 108 of Public Law 92-500 is working solely with control and management problems of urban and rural nonpoint source pollutants. As such, its scope is somewhat limited in that it does not deal with the broad spectrum of pollution problems, as 208 planning must; but from the standpoint of an educational and information program these differences are relatively unimportant. The strategies for education, for information dissemination and for technology transfer are basically the same.

The goal of the Washington County Project is to develop and institutionalize a sediment control mechanism for Washington County, Wisconsin. To accomplish this, technical information generated by physical scientists from an extensive monitoring network as well as legal and institutional alternatives developed by social scientists must be transferred to citizens and local decision makers to create an awareness of and support for those legal and institutional changes needed to control nonpoint source pollution. It should be made clear that the Washington County Project is operating at two levels: one, of course, involves the development of a specific sediment control mechanism or mechanisms for Washington County while the other involves the development of methodologies, strategies for implementation or whatever that can be generalized and utilized in other parts of Wisconsin, of the Great Lakes Basin and perhaps of the entire country.

Strategies for information dissemination and public participation in the Washington County Project were identified by project staff working with local citizens and county personnel. Initially, they involved two important assumptions. First, it was agreed that the general level of understanding and awareness of nonpoint source pollution was limited and thus, that early informational effort would have to be directed toward simply pointing out the problem and explaining some of the more basic--and technically well understood--processes and problems. Secondly, it was recognized that nonpoint source pollution is basically a people problem. Much of the problem can--and probably will--be solved if people are made aware of the causes and dimensions of the problem and of the fact that many of the things they do in everyday life can affect the problem. In urban areas, fertilizers and pesticides improperly applied to lawns and gardens are a problem as are grass clippings and leaves dumped in gutters. On farms, cattle watering in streams and manure spread on steep, frozen ground are significant nonpoint source pollution problems.

The public participation effort in Washington County is based on a fairly standard approach. To start with, key publics including service organizations, farm groups, garden clubs, environmental groups, and the like were identified within the county. A check list was made, each group contacted, and wherever possible, speeches were given which described the problem of nonpoint pollution, what the project was and how it--the project--was going to address those problems. This early effort was handled entirely by local (Washington County) project personnel.

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While this first round of speaking engagements was going on, a support staff was developed at the University of Wisconsin-Madison to generate materials to support the education and information program. A photographer was hired to record project activities specifically and nonpoint problems in general, to provide photographs for news stories and brochures, to gather slides for slide-tape sets and to take footage for a 16mm color film to be developed in the later stages of the project.

A print media specialist was engaged to write news releases for weekly and daily papers, to develop materials for specialized publications and to coordinate media activities. Graduate students and project staff were utilized for developing public participation strategies and for writing much of the necessary backup material.

A working group made up of the previously described individuals, project staff, and local and University Extension specialists was set up to oversee and coordinate the public participation effort, to review brochures, press releases and other written materials and to update and revise operational strategies.

In the first year of operation, all identified groups and organizations within the county were spoken to by project personnel. Two brochures--one on the project and the nonpoint problems and the other specifically on nonpoint source pollution--were written and printed. A slide-tape set describing the nonpoint problem and project activities was completed. A press tour of the Washington County Project and the closely related International Joint Commission project on the Menomonee River in Milwaukee was held and a series of news releases and feature stories were written for local weekly and daily newspapers. It is intended that this general level of backup or support activity will be continued throughout the life of the project.

Two additional public involvement strategies are currently being implemented. First, an extensive program for the schools involving grades K through 12 has been developed. Contacts have been made with teachers in the five public school districts and in private and parochial schools in Washington County. Problems of nonpoint source pollution and project activities were presented to them initially recognizing their dual roles as citizens and teachers. A graduate level seminar on the nonpoint problem will be offered to those teachers interested in utilizing in their classrooms materials developed by project staff. These materials will be work units on soil and water conservation, sedimentation, water quality, and the like which will be designed to fit into existing environmental education programs.

Funds are being sought to support a summer teacher training workshop both to increase the awareness and understanding of nonpoint source pollution and to develop additional curricula. An extensive evaluation of student's increased environmental awareness will also be undertaken in conjunction with the implementation of the newly developed curricula.

Secondly, a specific effort aimed at involving the broad spectrum of political leaders in Washington County in the project is being mounted. Sediment management and control will inevitably involve certain institutional changes and it is hoped that many of the required changes can be accomplished at the local level based on local understanding of and response to nonpoint source problems.

Quite obviously, concern for solving these nonpoint problems is not limited to Washington County. From the standpoint of the educational effort, the county is viewed as the jumping off place. Primarily through a process of repetition the education-information effort will build on itself. Through broader publicity and information dissemination the program becomes multi-county in scope, then region-wide, then statewide. Successful public participation strategies are utilized in other areas; new school curricula are made available to schools everywhere; written materials are broadened in scope to meet new needs.

Nonpoint source pollution abatement--perhaps more than any other environmental control effort--is a people problem and without public support, the programs necessary to control the problem will fall flat. It is relatively easy to generate public support for stopping point source pollution as it is generally a visible and easily understood problem. Nonpoint source pollution is a whole new ball game.

LAND MANAGEMENT INSTITUTIONAL DESIGN FOR WATER QUALITY OBJECTIVES

by

Carlisle P. Runge*

The problem of nonpoint source water pollution control is at once a problem of the interface of land use and water quality problems and a problem of federalism--the carrying out of policy in the intergovernmental framework. The purpose of this paper is to present the issue of nonpoint source pollution control in its historical/institutional contexts and to suggest principles of institutional design which respond to this context and which build on it, with emphasis on institutional patterns in Wisconsin and the experience of the Washington County Project.

INSTITUTIONAL ENVIRONMENT AND LEGACY OF NONPOINT SOURCE PROBLEMS

The set of nonpoint source problems should be seen, institutionally, as the combination of developments in water resources policy and land management. These two issues have developed along separate "tracks" through the history of the United States. Each requires examination in terms of institutions and authority at federal, state and local levels in order to establish a framework for approaching the problems of land related pollution control.

Water Resources Policy

Historically, the federal government has been the major force in water resources development and water quality planning, policy and allocation of resources. The Gallatin Report of 1808 was an early statement of the need for a nationally organized system of waterway improvements which would supersede the construction role of the states and private interests. This position was disputed, but was settled by the U.S. Supreme Court in 1824 in the classic case of Gibbons v. Ogden which recognized navigation and related water resource programs within Congress' authority to regulate interstate commerce (1).

On this authority, the federal government has established a tradition of direct implementation of numerous development programs for canals, dams and flood control, irrigation hydropower and other purposes. These began in the 19th century and continue in the work of the U.S. Army Corps of Engineers, and other federal agencies. Multiple objectives, and planning requirements have led to broader policy considerations which can be seen in the federal involvement in river basin planning over many years and federal concern for water pollution. Pollution abatement had been a modest responsibility of the U.S. Public Health Service since 1912 and was strengthened in 1948 (2). This function eventually shifted to the Federal Water Pollution Control Administration in the Department of Interior, signifying a broadening from health concerns to resource policy.

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Now, of course, water pollution abatement is the responsibility of the Environmental Protection Agency. The development of national policy, standards, regulation, and funding procedures can be traced through this history down to the comprehensive legislation of 1965 (P.L. 89.20) and in particular to P.L. 92-500 enacted in 1972.

The state role in water resources policy has been that of regulation of areas where the federal power has not been exercised, and recently, in serving as the agencies for the implementation of federal policy as defined in P.L. 92-500. State authority has been employed over the years, typically, for the regulation of municipal and private use of water resources. The emphasis has been on the use of water, or the direct effect on water, rather than on the direct state regulation of land use activities related to water quality.

In Wisconsin, examples of state involvement include the public health concern for municipal sewage reflected in the early version of Ch. 144 of the Wisconsin Statutes, enacted in 1919 (3). This law has been restructured several times and broadened to constitute much of the authority of the Wisconsin Department of Natural Resources in the water quality area. Additional state responsibilities included matters of water supply, diversion of waterways, groundwater, and industrial waste.

It is important to this discussion to appreciate that these were centralized regulatory functions carried out by the state with only modest delegation to local governments. The point source regulations of the State of Wisconsin, defined in Ch. 147, of the Wisconsin Statutes, in conformance with the National Pollution Discharge Elimination System of P.L. 92-500, follow this model.

The local role in water resources matters has been operational and relatively modest in regulatory terms when compared to federal and complementary state functions, as they have been conducted throughout our national history.

Land Management

The emphasis is very different in the historical direction of land management and its institutional structure. The rights of individual landowners and the state-local roles in the regulation of their activities have been the major forces in the development of institutions for land management in the United States. The federal role in the management of private lands has always been most limited.

Federal land policy reflects the historical concept of allodial tenure as the sine qua non of the development program of trans-Appalachian lands--reflecting social concern for individual freedom, a sharing of the wealth of the nation in a manner unencumbered by governmental (or feudal) ties, and for a democracy based on many small landholders. Thomas Jefferson led the fight against restrictions, or "entails", calling the small landholder, "the most precious part of the state" (4). Hence, federal policy was aimed at disposal in fee simple as enabled in the fundamental law of the Ordinances of 1785 and 1787 and subsequent federal enactments providing for the distribution and sale of the public domain. This line of policy culminated in the Homestead Act of 1862.

Continuing federal policy in the area of land management has been restricted to public lands under proprietary control and *incentives* for state and local land management as illustrated in the Costal Zone Management Act of 1972 and the proposed national land use planning *assistance* legislation which has been before Congress in several forms in recent years.

The authority to regulate the private use of land has been reserved for the states through their police power, and other means. Traditionally, these powers were delegated to local units of government which developed land management ordinances, including zoning which was upheld by the U.S. Supreme Court in the *Euclid v. Ambler Realty* case in the 1920's Other codes have augmented local authority.

The states in the 1970's have attempted to recapture some of their authority, earlier delegated, through the development of state land management programs. This trend was described in *The Quiet Revolution in Land Use Control* by Fred Bosselman and has since been presented in numerous publications. Yet it is important to note that only eight states conduct planning and regulation of some areas of private land use on any sort of comprehensive basis (5), and of these only Vermont, Maine and Hawaii directly regulate landowners. Most states either review the activities of local government, or define areas of "state interest" or larger than local impact for intensive review, or, in some cases, regulation. These generally include critical resource areas, or major developments such as power plants. What is significant is that a great deal of state land management responsibility remains delegated to local goverments and is not conducted in the centralized fashion of water quality regulation; point source control being the major example of centralized water pollution control.

Local governments remain closest to the numerous individual landowners and occupiers and carry the burden of land management, or regulation of private landowners. Despite other influences, particularly state policies, land use retains this local emphasis. It is evident not only in the traditional land use controls which are based on the police power, but also in the history of federal soil conservation programs. Since the 1930's, federal policy objectives have been carried out at the local level through state-local institutions--the Soil and Water Conservation Districts. Federal staff involved at this level serve a technical assistance function to local institutions, rather than an administrative function.

The differences between the development of water resources versus land management policy is quite clear with respect to the degree of direct federal policy which is applicable to specific local conditions and how this policy is executed. Federal emphasis in the water resources area remains significant and direct, although in some cases it is administered through the states. In land management, activity is primarily at the local level, with state prerogatives for assuming its soverign authority in the background, but little direct involvement of the federal government, except through technical and financial assistance.

IMPLICATIONS

What these two lines of institutional development imply is that institutional design in the nonpoint source area must create a linkage between water resources and land management frameworks. This does not only mean the association of land management programs with water quality goals. It also raises a complex problem of federalism, of how best to relate national policy and resources to the executory powers of the several states and to their local units of government with their diverse experiences and environments.

The association of land and water programs suggests a set of relationships which would attempt to take advantage of existing interfaces and which would improve vertical and horizontal coordination in order to best utilize existing resources.

PRINCIPLES OF INSTITUTIONAL DESIGN

At the most general level, the institutional approach suggested by this brief review requires the recognition of existing authority at all levels of government, major sources and channels of resources, and ongoing program responsibility, as it is now practiced. More specific design principles attempt to build on potentials for coordination and existing models for cooperative implementation of programs, particularly between states and their local governments and also between state structure and federal agencies which operate in the several states.

The following observations may serve to respond to some of the different areas of emphasis outlined above:

1. Overall policy and major funding sources are clearly lodged at the federal level in the national water quality policy stated in P.L. 92-500 and in the programs for planning assistance, cost sharing and technical assistance which are available from E.P.A. and the U.S. Department of Agriculture.

2. Consistent with federal policy, the guidelines for institutional design and standards for the performance at the local level may be most suitably the responsibility of the states. These guidelines and standards should include criteria and assistance for local regulation or implementation. Additionally, state coordination of funding which might "pass-through" from federal sources to local institutions would be indicated.

In Wisconsin, the Floodplain and Shoreland zoning programs are examples of a state agency with water quality responsibility (DNR) working with local units of government to implement a state policy through local institutions. The programs are examples of land management programs with water quality implications. The well-known Just v. Marinette County case (Wisconsin Supreme Court, 1972) upheld the Shoreland program and illustrated the substantial impact on private lands of regulation for water quality purposes. The nonpoint source problems presents an even more complex set of concerns, due to the far greater number of affected landowners and occupiers. This is further evidence for the need to develop a framework which is supported by state standards, but which would not be administered by the state unilaterally.

3. The local level of government and institutions appears then to be well suited for the actual execution of nonpoint source control programs. The experience of local institutions in land management through the devices of land use controls, and also, the conduct of soil and water conservation programs, and the distribution of cost sharing funds to farmers for management practices, suggests that there are relationships now established between these institutions and landowners which can materially assist in the implementation of a comprehensive nonpoint pollution control program.

4. Coordinated efforts between local institutions like the Soil and Water Conservation Districts and the planning and regulatory elements in local government well could be the "cutting edge" of an eventual program. A coherent set of relationships between state and local institutions appear to be essential in developing the program. Further support may be desirable from regional institutions, such as Regional Planning Commissions and the district level units of both federal and state agencies. At the state level, the Department of Natural Resources and the Board of Soil and Water Conservation Districts should be appropriately related.

CONCLUSION

These general principles of institutional design and observations suggest a substantial local role in program implementation based on state guidelines and standards, which, in turn, carry out federal policy; all should be seen as an institutional arrangement which is conditioned by the historical experience of the separate approaches to water resources and land management in the United States. They are consistant with Constitutional precepts and legal history which limit the federal role in private land management in favor of authority reserved for the states and conducted locally in most instances. They also recognize the degree of federal influence in water resources matters which is a policy of long standing. The administrative experience of numerous institutions at the several levels of government is incorporated into such a possible approach. These observations include an appreciation of the social traditions and values which are associated with the holders of land in America. Finally, these considerations have a bearing on the degree of public management of private lands, the levels of government and the issues of private-public cooperation, responsibility and allocation of costs and expected benefits.

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PLANNING DIFFUSE POLLUTION CONTROL

by

Robert Schneider

Section 208 of the 1972 Federal Water Pollution Control Act (Public Law 92-500) has forced planners to consider programs regulating nonpoint pollution; particularly the runoff of sediment and nutrients from rural and urban land. The task appears formidable, requiring the synthesis of concepts ranging from those associated with the discipline of economics to those more likely to be found in the literature of geomorphologists and water chemists.

This paper is designed to aid planners in conceptualizing and designing nonpoint pollution control programs. It's central concern is the design of legislation achieving a socially optimal allocation of water resources among various competing uses, i.e., the assimilation of waste vs. recreational, aesthetic and others. Achieving this allocation demands consideration of the various physical properties of the pollutants, their impact on water quality, and the public's perception of and desire for quality water. The framework developed below makes explicit the physical and social dimensions of the nonpoint pollution problem. It should prove useful in analyzing pollution control regulation as well as determining priorities for nonpoint pollution related research.

The economists' general paradigm for efficient allocation of resources is reviewed, and a conceptual model is considered to incorporate the specific analytical problems of nonpoint pollution. Finally, an analytic framework corresponding to the conceptual model is suggested and used to develop an approach to legislation based on a system of classification of polluters on the basis of their potential to impose damages.

COSTS AND BENEFITS

For water quality as for other desirable goods and services, social well-being is promoted when the difference between its cost of production and the accruing benefits is maximized. A hypothetical relationship between the benefits and costs associated with a range of pollution reduction is graphed in Figure 1. Costs are assumed to increase at an increasing rate and benefits increase at a decreasing rate. The assumption of increasing cost implies that those interested in reducing pollutant yield will rank all possible means of control from the least to the most expensive, increasing pollution reduction through the application of more expensive techniques only after all cheaper techniques have been implemented. The decreasing benefits assumption implies that as water quality continues to improve the public's perceived benefit from further increments of improvement decreases. For example, at point (a) benefits are rising faster than cost and further pollution reduction is desirable.

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A change from level "a" of pollutant reduction to level "b" increases the excess of benefits over cost. A further increase from "b" to "c", however, would not be in the public interest. Such a move results in loss of net benefits, the increase in costs being greater than the increase in benefits.

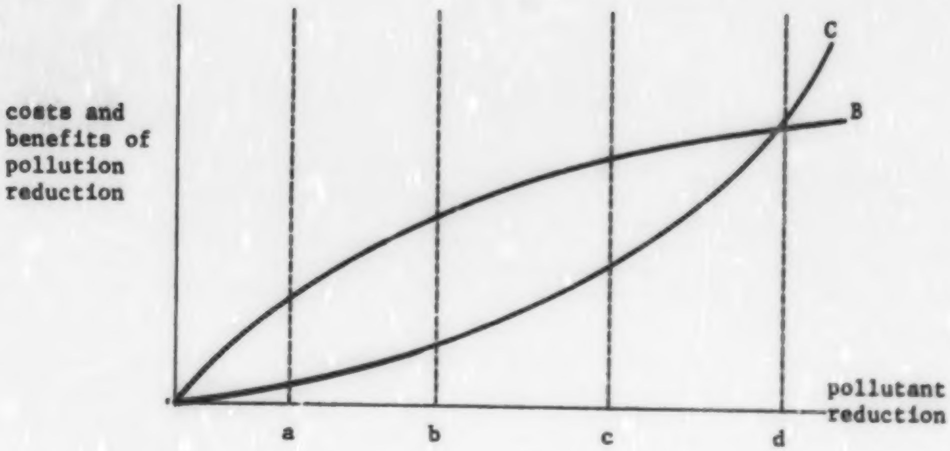

Figure 1. Optimal Level of Sediment Reduction (b)

However, Figure 1 demonstrated the need for information about the shape of the cost and benefit curves associated with different levels of sediment reduction. The problems of estimating such cost and benefit curves are great. Although one strives to design legislation capable of achieving point (b) for all polluters and waterbodies, the state of the art allows neither such a precise estimate of the costs and benefits nor the implementation and enforcement of laws sufficiently discriminating to achieve this optimum.

Approximating the cost and benefit relationship of Figure 1 requires a great deal of technical knowledge about the physical characteristics of pollutants and their interaction with the environment. This knowledge may be conveniently placed into four categories: (1) cost of pollutant control, (2) the delivery of pollutants to points of economic damage, (3) water quality response to changed pollutant loads and how to measure it, and (4) the water quality indicator/waterbody value relationship. Figure 2 presents a conceptual model of these relationships which will be developed in the next section.

DEVELOPING A POLLUTER CLASSIFICATION SCHEME

In this section the relationships shown in Figure 2 are developed into a scheme for classifying polluters according to (1) their potential to impose downstream damages and (2) the costs they incur in reducing their pollutant load. The objective of this scheme is to aid policy-makers in equating incremental pollutant reduction costs and benefits without incurring administrative and enforcement costs overshadowing

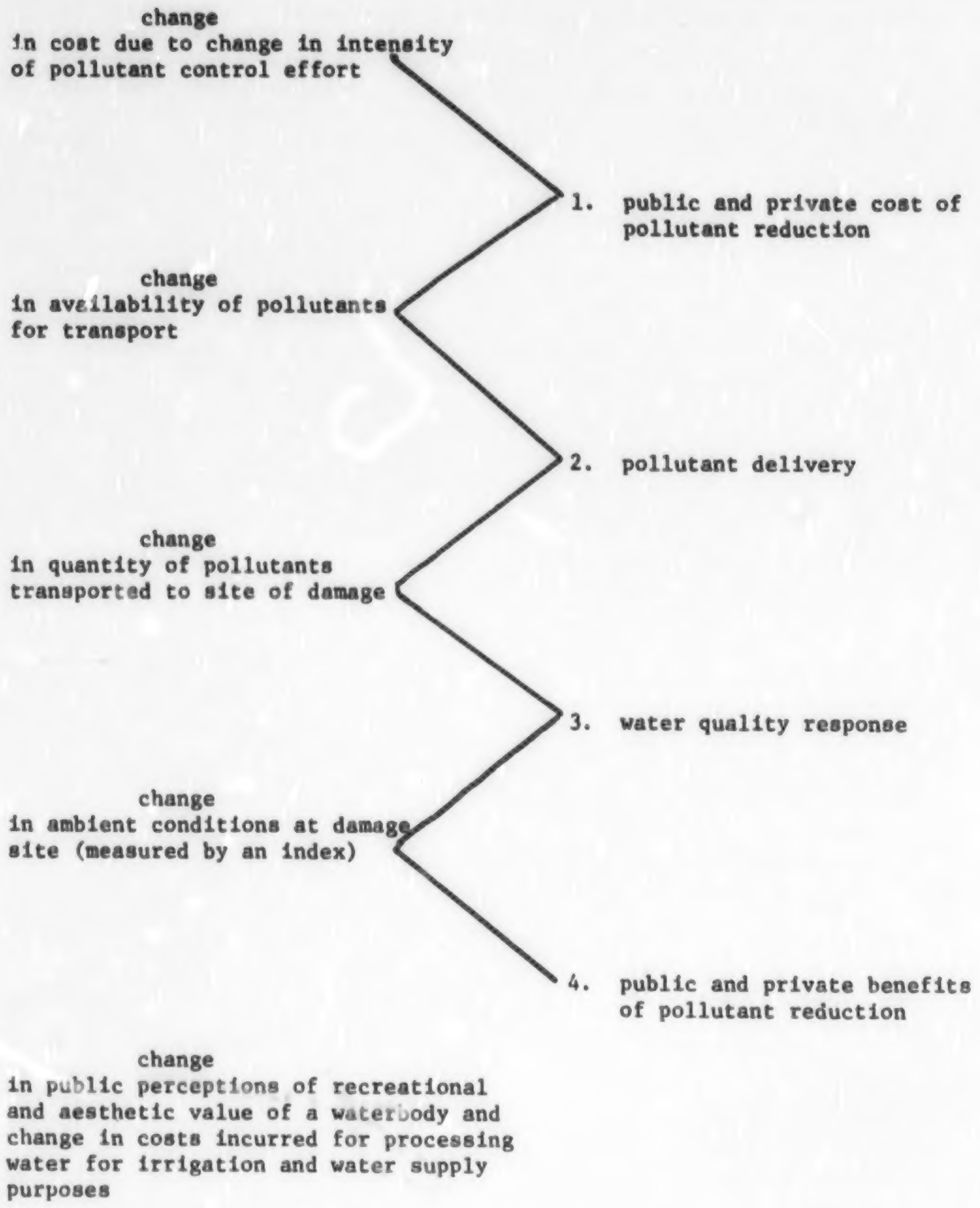
change in cost due to change in intensity of pollutant control effort
1. public and private cost of pollutant reduction
change in availability of pollutants for transport
2. pollutant delivery
change in quantity of pollutants transported to site of damage
3. water quality response
change in ambient conditions at damage site (measured by an index)
4. public and private benefits of pollutant reduction
change in public perceptions of recreational and aesthetic value of a waterbody and change in costs incurred for processing water for irrigation and water supply purposes

Figure 2. Conceptual Model for Evaluating Costs and Benefits of Pollutant Reduction

savings resulting from such a distriminating "efficient" policy.

The method of the suggested scheme is to assign each polluter to a subcategory in each of the four main categories of relationships discussed. The four main categories are: (1) cost of control, (2) delivery, (3) response, and (4) value. The subcategories are determined by characteristics that strongly differentiate potential polluters within each of the four major categories. The number of useful subcategories depends on the homogeneity of the entities considered. If, for example, all waterbodies in a planning area were identical in terms of their value determinants (location, phsiography, etc.) and their water quality response to a changed pollutant load, there would be no subcategories under categories 3 and 4. Examples of characteristics important to the determination of subcategories are given in Table 1. Figure 3 demonstrates how such a system might function. Three curves are estimated for each category. Each curve represents a subcategory and each is estimated under assumed conditions with respect to the determinants of Table 1. Changing these *ceteris paribus* conditions may change the parameters of the relationship between the dependent and independent variable (Figure 3.2) or may change the functional form completely (Figure 3.3). The system depicted in Figure 3 classifies each potential polluter into one subcategory in each of the three graphs. The resulting hypothetical system contains a possible 81 (3^4) schedules which may be combined to

Table 1. A Classificatory Scheme: Determinents of Subcategories

	Category			
	1 Cost of control	2 Delivery	3 Water quality response	4 Value response
Subcategory determinants	Rural farm size farm product soil type farm physiography livestock conc. Urbanizing physiography development size Urban size of region storm sewers	Location in watershed Drainage network in watershed Other land use Watershed size	Lake/stream PH size depth hydraulic-residence time present eutrophic state temperature	Other site characteristics Distance to population center Substitutes

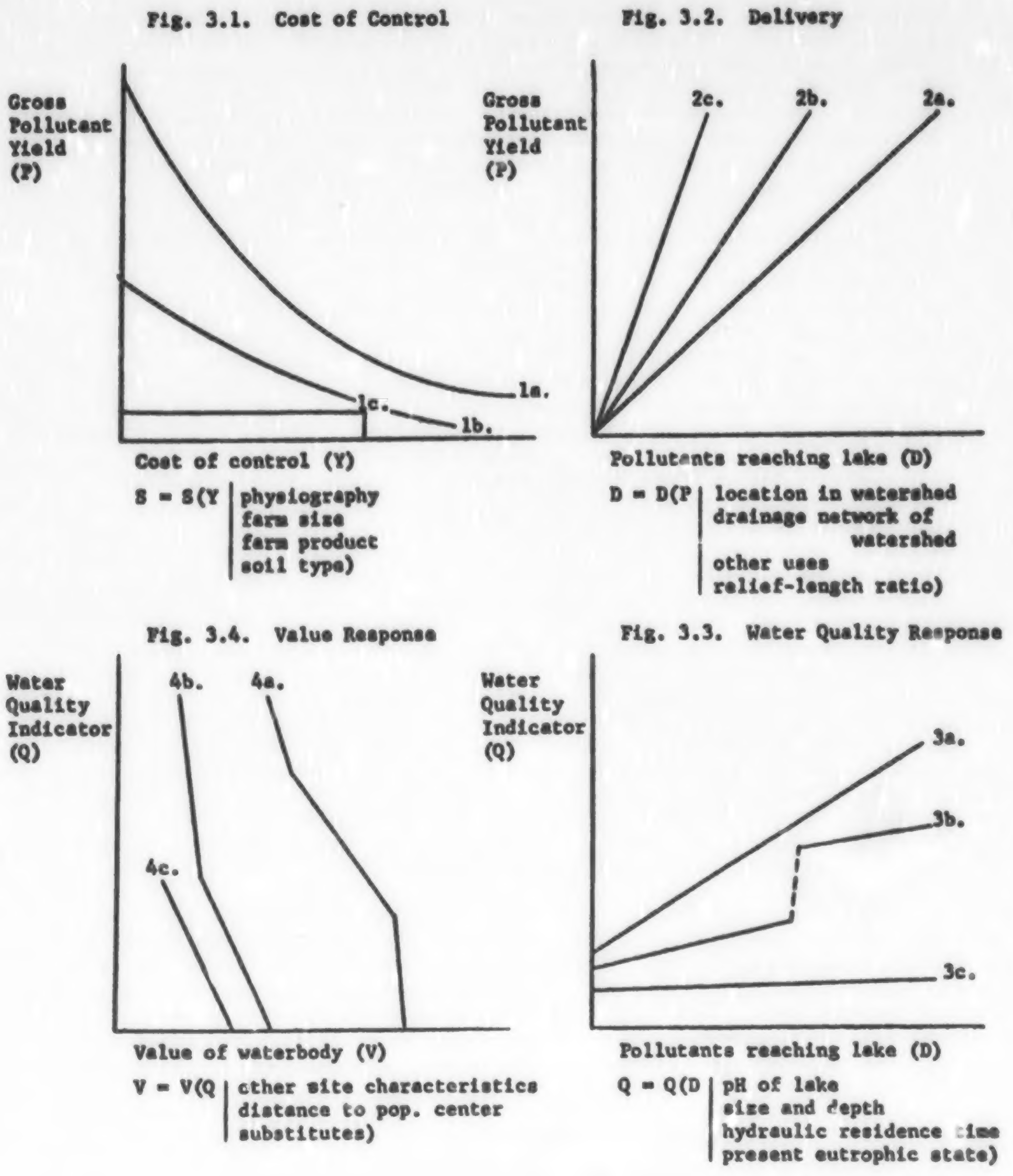
Fig. 3.1. Cost of Control
Gross Pollutant Yield (P)
1a.
1b.
1c.
Cost of control (Y)
S = S(Y | physiography
farm size
farm product
soil type)
Fig. 3.2. Delivery
Gross Pollutant Yield (P)
2c.
2b.
2a.
Pollutants reaching lake (D)
D = D(P | location in watershed
drainage network of watershed
other uses
relief-length ratio)
Fig. 3.4. Value Response
Water Quality Indicator (Q)
4b.
4a.
4c.
Value of waterbody (V)
V = V(Q | other site characteristics
distance to pop. center
substitutes)
Fig. 3.3. Water Quality Response
Water Quality Indicator (Q)
3a.
3b.
3c.
Pollutants reaching lake (D)
Q = Q(D | pH of lake
size and depth
hydraulic residence time
present eutrophic state)

Figure 3. Representation of a Hypothetical Polluter Classificatory System

represent a given polluter and determine the level of reduction to be imposed upon him. Figure 4 illustrates the procedure. Consider two farms, each in its respective watershed. The farms, watersheds, and lake values (Figures 4.1, 4.2, 4.4) are identical in every way. The water quality response of the lakes to the pollutant is different (Figure 4.3), however. Lake A responds discontinuously at a "critical level" of the pollutant. Lake B, on the other hand, is less responsive but continuously so.

Figure 4.1 depicts increasing cost of pollutant control. Figure 4.2 assumes that 83 percent of the pollutants produced on the farms gets to the lakes. Figure 4.3 shows the water quality response of each lake to pollutant reduction. Lake A responds fairly markedly from G_0 to G_1, has a critical area from G_1 to G_2 and is relatively unresponsive from G_2 to G_3. Lake B responds continuously but is less responsive than A from G_0 to G_2, but more responsive thereafter. That the potential for A to achieve good water quality is not as high as B is evidenced by their respective intercepts with the water quality axis. Figure 4.4 represents the public's valuation of the lakes at various levels of water quality. The shape of the curve represents the fact that the value of a waterbody is less responsive to water quality changes at the extremes of good and bad than it is near the average, i.e., below a certain level it is undesirable for any water related activities and above a certain level further improvement does not significantly change people's behavior or perceptions. The major value changes take place near the midpoint; a slight improvement allows the lake to support a new activity, i.e., boating, game fishing, swimming, snorkeling, or scuba diving. Thus, lake A, possessing low water quality potential, can never obtain the changes in value to pollutant reduction achievable by lake B. Comparing the return on the equal increments of pollutant control costs of Figure 4.1, it can be seen that a cost of C_0C_1 for each farm returned a benefit of A_0A_1 for lake A and B_0B_1 for lake B. A further increase in cost of C_1C_2yields a benefit of A_1A_2 to lake A and B_1B_2 to lake B, etc. It is evident from this diagram that only the initial outlay for pollutant control is of significant benefit for lake A. For lake B, however, further costs continued to yield "substantial" benefit.

In application these curves can be presented as schedules as shown hypothetically in Table 2. This table demonstrates that in watershed A it pays to incur the first 10 cost units of control, but further costs are unwarranted. A second 10 cost units, for example, would only yield one benefit unit. In watershed B, on the other hand, costs up to 20 units are warranted. Using these schedules to prioritize control expenditures, a planner would make the following recommendations: (1) apply 10 cost units to A to reduce the on site pollutant yield from 30 to 15 pollutant units; (2) apply 20 cost units to B to reduce on site pollutant yield from 30 to 6.5 pollutant units; and (3) further costs are unwarranted.

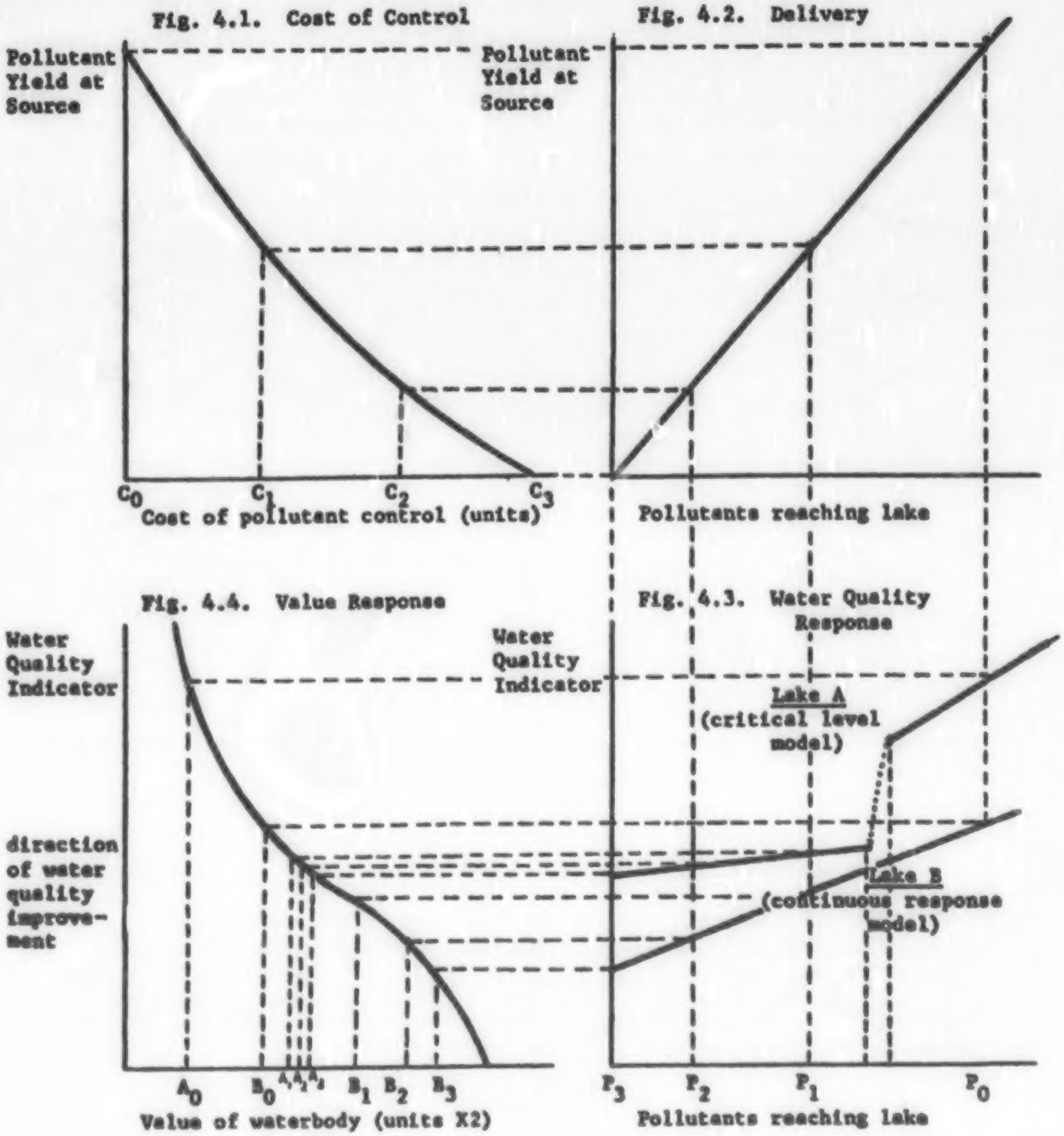
Fig. 4.1. Cost of Control
Pollutant Yield at Source
C_0
C_1
C_2
C_3
Cost of pollutant control (units)
Fig. 4.2. Delivery
Pollutant Yield at Source
Pollutants reaching lake
Fig. 4.4. Value Response
Water Quality Indicator
direction of water quality improvement
A_0
B_0
A_1
A_2
A_3
B_1
B_2
B_3
Value of waterbody (units X2)
Fig. 4.3. Water Quality Response
Water Quality Indicator
Lake A (critical level model)
Lake B (continuous response model)
P_3
P_2
P_1
P_0
Pollutants reaching lake

Figure 4. Analytic Procedure for Determining the Optimal Level of Pollution Reduction

Table 2. Hypothetical Schedules for Determining Optimal Pollution Reduction Strategy

Marginal cost of control	Cost of control	Pollutant yield at source	Pollutants reaching lake	Water quality indicator	Value of waterbody	Marginal value
	0	30	25	20	k	
10						20
	10	15	12	11.0	k+20	
10						1
	20	6.5	5	10.5	k+21	
10						2
	30	0	0	10	k+23	
	0	30	25	12	k+14	
10						14
	10	15	12	9	k+28	
10						11
	20	6.5	5	7	k+38	
10						6
	30	0	0	5	k+42	

SUMMARY

A framework was developed formalizing the evaluation of costs and benefits of nonpoint pollution control and making explicit the informational requirements necessary to the analysis. Its usefulness in designing discriminating legislation was considered. Such a scheme should prove useful in (a) developing a system of classification useful for efficient nonpoint pollution control, and (b) determining areas of major research priority to aid in the development of nonpoint pollutant control.

BEST MANAGEMENT AND TREATMENT PRACTICES
FOR
WATER QUALITY

by

Gregory L. Woods[1]

The philosophy of planning and applying land treatment practices in the Black Creek Watershed has changed. This change does not reflect a change in the objectives of the project. But, it is basic to effective, efficient land treatment practices as it addresses itself to maintaining water quality, first, and to sound soil conservation second. Identifying management and treatment practices which are most pertinent to water quality is necessary and right. A diverse broad-spectrum practice approach, is sound conservation, but it does not zero in on getting at water quality. A task, which in Black Creek is bounded by a fixed time frame. And, in this day when the american farmer must produce more, BMP's encourage him to do that without foregoing land and water protection.

Selling management and treatment practices on individually owned land is a complex sociological, economical and chronological chore. The mechanics of planning management and treatment practices, however is rather basic. The planning process has three basic alternatives: (1) land use change, (2) crop rotation change, (3) and, practice installation.

In evaluating a farm, each field or farming unit is analyzed for basic soil loss using the universal soil loss equation. The equation, our only tool for estimating soil loss is shown as:

$A = RKLSPC$, where
A = is the computed average annual soil loss per unit area
R = rainfall factor
K = soil erodibility factor
L = slope length factor
S = slope steepness factor
C = cropping management factor
P = is the erosion control practice factor

It is readily seen that of the six factors only three can be significantly changed or altered by man. Rainfall, soil erodibility, and slope steepness always remains static.

It is necessary to distinguish the different types of erosion areas, and their relationship to the universal soil loss equation. Within the context of "non-point" pollution from agriculture land we have "point" and "non-point" areas.

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[1] District Conservationist, Jasper and Newton Counties, Indiana. USDA Soil Conservation Service, R.R. #1, Box 19A, Rensselaer, Indiana.
Former Soil Conservationist in Allen County for the Black Creek Sediment Control Project.

A "point" area is defined, where a single source of erosion can be treated with a single management practice providing a long term solution.

These are areas usually not farmed actively and their use does not provide significant income. Nor as these areas related to the factor in the universal soil loss equation and the soil loss cannot be accurately estimated.

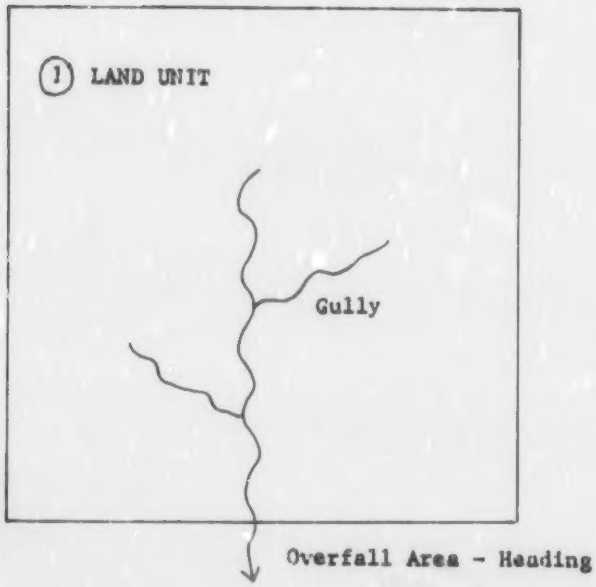
Example of practices falling into this category would be streambank protection, critical area planting, grade stabilization structure, and grassed waterway.

A "non-point" area is defined, where a diverse source of erosion requires a series of management practices working together yearly to provide a long term solution.

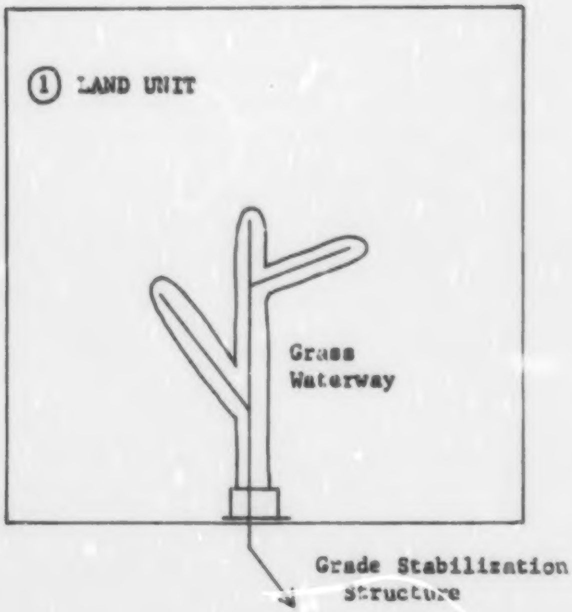
These areas of land are usually actively farmed and their use provide income. These areas relate to the factor in the universal soil loss equation and the soil loss cannot be accurately estimated.

Example of practices falling into this category would be minimum tillage, parallel tile outlet terraces, pasture hayland planting, and conservation cropping system.

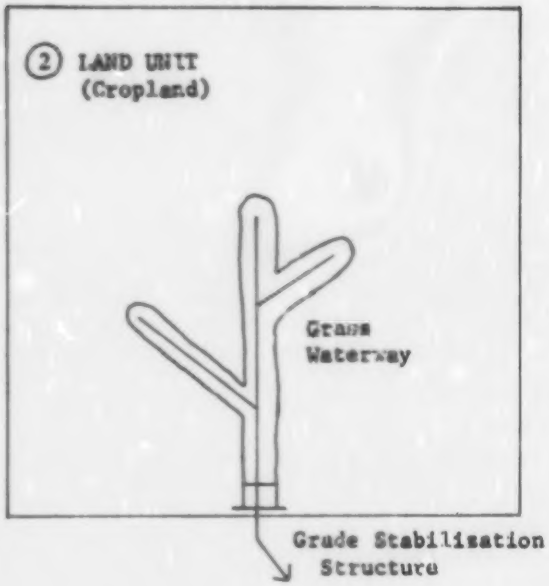
The objective is to obtain a long-term committment of management practices which provide erosion control and water quality on the "non-point" source area.


① LAND UNIT
Gully
Overfall Area - Heading

Despite the land use in a land unit - a gully and "heading" are recognizable "point" sources of erosion and sediment.


① LAND UNIT
Grass
Waterway
Grade Stabilization
Structure

Despite the land use, by constructing a stable grass waterway and grade stabilization structure where the gully and "heading" were, the "point" sources of erosion and sediment have been solved.


② LAND UNIT
(Cropland)
Grass
Waterway
Grade Stabilization
Structure

Despite money and time invested, in solving the "point" sources (gully and heading) by grass waterway and grade stabilization structure, without a change in; 1) land use, 2) crop rotation, 3) practice installation;

Given S = 4% slopes
C = Continuous corn
P = Cross-slope, fall plow

the grass waterway and grade stabilization structure become a means of sediment transport with no effect on "non-point" erosion, and limited influence on water quality.

This fact reinforces the need to find a series of practices which are farmable and sellable, which provide dual benefits of erosion reduction and improved water quality which are relatively maintenance free, and which above, demand a permanent committment and support from a landowner. These types of practices require other related practices for support. For example, to properly plan and install a PTO Terrace System one must have satisfied the need and process for tillage methods, conservation cropping system, tile drains and contour farming. This practice gets to the root of the problem of upland erosion by leaving the landowner with a comfortable rotation, better drainage, better field topography, besides meeting the fundamental water quality objective.

Maintenance of high quality water, demands development of agricultural practices that will minimize pollution of surface and ground waters. Hanway and Laflen[2] studied several PTO terrace systems over a three year period found that they reduced surface water yields at least 30%, and sediment output loads average about 4.5% of estimated erosion between terraces. Average total P concentrations (P) were highly correlated with the sediment amounts in runoff.

Tremendous soil loss can be reduced by minimum or conservation tillage. When a landowner invests $5000 to $8000 for a new no-till planter, or modifies his present planter, one feels that a firm committment has been made. If conservation tillage is being performed, so is crop residue management. And very seldom when either PTO terraces are constructed or conservation tillage performed, do we have to worry about sedimentation from those fields.

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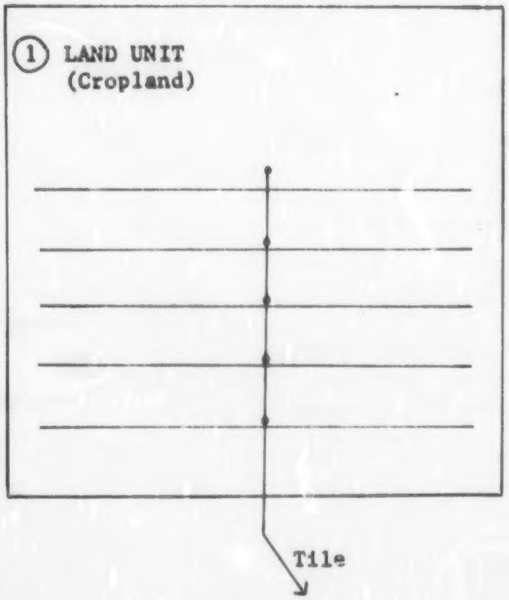
[2] Hanway, John J. and Laflen, John M., Professor of Agronomy, Iowa State University, Ames, and Agricultural Engineer, North Central Region, ARS, USDA, Ames, Iowa, (respectfully).



Parallel Terraces
-or-
No-till Planting
-or-
Contour Strip Farming
-or-
Cons. Cropping System

Despite land use, erosion is within soil loss limits and water quality has permanently been enhanced by altering permanently one factor of the soil loss equation - - "slope length."

BEST MANAGEMENT & TREATMENT PRACTICES

I. Parallel Tile Outlet Terraces
    A. Conservation Cropping System
    B. Tile Drain
    C. Contour Farming
    D. Stripcropping
    E. Tillage Operation

II. Minimum Tillage
    A. Crop Residue Management

III. Pasture and Hayland Planting

IV. Streamchannel Protection & Stabilization
    A. Critical Area Planting
    B. Livestock Exclusion

SUMMARY
EVOLVEMENT TO BEST MANAGEMENT PRACTICES

I. Emphasis on water quality and erosion control. Although total erosion control may not be reached on certain lands, best management practices will provide water quality.

II. Public dollars for public benefit.

III. Other conservation practices encumber many dollars which may not provide significant results.

IV. BMP's require less man power for planning, follow-up, engineering, and compliance.

V. Many BMP's are economical, provide for an economic return, make common service, are farmable and provide a minimum of change in the crop sequences.

IMPLEMENTING AND MONITORING CONSERVATION PLANS

by

Thomas D. McCain[1]

Reviewing land treatment accomplishments in the Black Creek Sediment Study Project as we complete this fourth construction season, reflects interesting changes in attitudes of technicians, planners and the people of the watershed. The current emphasis on major management objectives has been a modification of original ideas. When the initial work plan was assembled four (4) years ago there was conserted effort by the Allen SWCD, SCS and Purdue University people to accumulate, analyze and evaluate all the resource data available for Black Creek. Even looking back to the initial review of the Maumee Basin we set out to find a difficult situation where some type of "demonstrational" applied land treatment program could accomplish the desired objectives. Black Creek was selected as the most typical mini-basin.

INITIAL PLANNING PHASE

In initial planning phases, soils and other related maps were used to help analyze the needs of the watershed. The review of existing conservation plans prepared for a limited number of SWCD cooperators within the watershed was an asset. These old plans gave a clue as to the land treatment of the past and the potential acceptance by some land users.

As the work plan began to take shape, several objectives relating directly to the needed land treatment began to unfold. Our task in SCS was to provide planning and application assistance to every cooperative landowner or group. We were committed to developing a complete conservation plan before the SWCD could cost-share on individual practices.

At First, Drainage Is Most Popular

Many times the farmers own assessment of needs and our assessment of their needs are very different. Drainage improvements rate "high" in the minds of farmers when given this opportunity to receive cost-sharing. Several Black Creek practices are basically "sediment control" but are popular with farmers because they maintain the drainage system.

We choose not to emphasize drainage even though this is necessary to adequately treat soils with severe wetness hazards. There are aspects of drainage however, that become an integral part of erosion control practices such as tile under waterways and tile for parallel tile outlet terraces.

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[1] District Conservationist, Allen County, Indiana, U.S.D.A. Soil Conservation Service, 2010 Inwood Drive, Fort Wayne, Indiana 46805.

A Myriad Of Practices Were Selected

A "committee approach" was used to the development of Table A-10. We grouped conservation practices and asked individuals with expertise to evaluate needs and develop practice specifications that could be used for cost-share purposes. As we might reflect now, we "threw the book" at Black Creek in numbers of conservation practices and considered many land treatment combinations available to the cooperators of the watershed. In retrospect, it might have been better to have decided upon 8 or 10 practices that best served the needs.

Early Plans Contained Too Many Practices

It has been a "nightmare" in conservation plan follow-up -- many practices are in conservation plans which are not mandatory but were agreed to by the cooperator at the time of planning. These non-mandatory items fall by the wayside and have not been agressively used. Thus many of these non-essential practices have been weeded out after the "grace period" has expired.

All resource development projects involve the developments of human interest as a desire for conservation. We went knocking "door to door" in the early stages to secure cooperators. This effort and the efforts of the Purdue sociologists helped make many people aware of the Black Creek Program. We still recognize that the old SWCD cooperators were instrumental in getting us started in the field. These people readily accept new ideas and by their own progressive nature have been successful farmers in their neighborhood.

Existing Cooperators Provided A Starting Point

These early cooperators formed the nucleus of the Black Creek Group, and had it not been for this Black Creek group, there would not have been the 140 thousand dollars of private funds collected for development of the group drainage and erosion control measures on Black Creek and its tributaries. The Black Creek group reflected their own priorities in development of drainage outlets. However, letting landowners take a free hand in promoting drainage in channel modifications has not complimented the total program. This last statement may not be a very acceptable point with the local people, but their efforts to get Black Creek activities underway gave a "showplace of something" for which they are to be commended.

The Black Creek group is to be commended for their immediate action and forcefulness in getting cooperation from as many people as they did. It was fortunate that they were well organized as a group even before Black Creek became a viable project. Some things accomplished by the group were, as Dr. Karr might put it, "cosmetic" and only added to the attractiveness in the farmer's eyes rather than as true erosion control. However, general improvement throughout the watershed was the most instrumental thing in opening the eyes of other potential cooperators to the efforts being made on individual farms.

Just as we were fortunate in working with Joe Graber very early in the program, perhaps he used us as a testing ground for his own people. Mr. Graber gave us an opportunity to apply a considerable total land treatment program on an Amish farm. The effects of livestock exclusion with the fencing and field borders on the Graber farm served as a tour stop and focal point many times. We overused many areas for "show and tell" during the early years because they were perhaps few and far between.

Now we can reflect on what we have learned and the attitudes of farmers in terms of an acre by acre approach to sediment control.

MONITORING WATER QUALITY

Conservation today cuts across traditional ideas by focusing on water quality goals rather than strictly on soil loss limits when planning erosion control management systems. Land users may be applying practices that allow moderate soil movement within a farm, but such that, they are able to recover or reuse sediment within the farm.

Conservation planning to meet water quality goals will require the application of practices which will better control annual soil losses, rather than relying strongly on crop rotations to protect soil productivity. In reality soil productivity will not be depleted if water quality goals are practically achieved. In other words, the installation of terrace systems and sediment basins for control of soil loss from farms, coupled with cropping rotations, conservation tillage, crop residue use and all the other traditional management practices, will provide the necessary control.

Conservation today, places a high priority on applying cultural (management) practices in combination with structural control (terraces, waterways, structures, etc.) treatment.

Land Treatment Goals Must Be Realistic

Setting goals too high may be a mistake. "Treating each acre according to its needs" may not dictate the same priorities for SCS assistance in the future. Even within a farm, the approach may be taken from the standpoint of: doing something in a positive way on the most critical area of the farm may be better than doing nothing because an entire conservation plan was not acceptable or possible.

For many years SCS technical guides have defined many conservation practices, each with pages of explicit specifications. Often we found ourselves unable to complete a basic conservation plan due to the inability of a cooperator to modify his operation -- thus the loss of our productive time and the opportunity to accomplish water quality goals.

The ability to modify specifications and planning requirements in the Black Creek project has increased flexability considerably. Progress charts also point out areas of greatest success. Cost-share payments now have been higher than necessary but the short duration of the project demanded rapid application.

THE FUTURE OF CONSERVATION PLANS

The next main item of importance, is the possibility that future land use regulations may require conservation plans to be prepared. A mandatory adherence to these plans follow. Some practices are much more difficult to assure continued success than others. As an example, full use of annual management or cultural operations makes frequent, on-site inspections necessary to determine compliance. The installation of permanent conservation practices makes compliance determination easier.

Perhaps another way to look at this is to analyze the cooperators involvement in this plan. If a conservation practices such as terraces is necessary and appropriate, then the farmer will likely contract this work for a specified amount of money to be installed in a short period of time. This will not involve much of the farmers own time, machinery, or concern.

Farmers Are Very Independent - And Proud

Last spring (1976), several prominent farmers had equipment capable of performing minimum tillage practices but instead they performed the opposite (maximum tillage). A very favorable warm early spring with prolonged days suitable for field operations caused this to happen. These farmers with their large tractors and enormous tillage tools would have idle time if they were not in the field. Many felt compelled to work and rework their ground with fear the weeds would get ahead of young crops, or their neighbors might wonder why they weren't busy, or just the old pride of having the best seedbed in the neighborhood.

We must work toward a few conservation practices that touch potentially every acre of cropland down to the last square foot and these practices must be proven to be a desirable method of reducing soil loss. Originally the 33 land treatment practices identified in the Black Creek work plan presented a myriad of planning challenges. Now in the retrospect perhaps it would have been best to identify 8 or 10 basic conservation practices for Black Creek watershed which are the most dynamic in helping meet acceptable water quality standards. The Black Creek program serves as a proving ground whereby we have narrowed the time frame in finding some answers to our water quality objectives to four years.

Who Will Write The New "Rule Books?"

We find todays conservation work includes a greater involvement of agencies, organizations, and people. Some people may want all out water quality without knowledge or respect for agriculture. We must modernize our approach as we meet these new challenges and we must not forget the farmers interests. We are trying to satisfy our total society. Perhaps now we have a new "rule book" to live by. Water quality standards when presented to the land user in the proper perspective can be attained, we can meet these goals if we COOPERATE!

AN INSTITUTIONAL APPROACH TO IMPLEMENTING BEST MANAGEMENT PRACTICES

by

James E. Lake[1]

The Black Creek Study, one of three section 108 projects funded by Region V of the United States Environmental Protection Agency is presently finishing its fourth year of activity. The project is scheduled to last one more year, ending September 30, 1977. The formal name for this study is Environmental Impact of Land Use on Water Quality, however it is more commonly referred to as the "Black Creek Study." The Allen County Soil & Water Conservation District, Allen County Indiana, accepted the 1.8 million dollar grant from EPA in October of 1972.

The main purpose of the study is to attempt to determine the role that agricultural pollutants play in the degredation of water quality in the Maumee River Basin and ultimately Lake Erie.

The project was designed and developed by a consortium of the U.S. Environmental Protection Agency, the U.S. Soil Conservation Service, Purdue University, the office of U.S. Congressman J. Edward Roush, and the Allen County Soil & Water Conservation District. It is a response to allogations first brought to the attention of Allen County residents at a conference on the future of the Maumee River, sponsored by Congressman J. Edward Roush in January of 1972. At that conference sediments and related pollutants were named as major contributors to the degredation of water quality in Lake Erie. It was further suggested at that conference that agricultural operations significantly increased the amount of sediment and sediment related pollutants in the Lake. Through the Black Creek Study we are attempting to realistically define the role that agricultural operations play in the pollution of the Maumee River, Lake Erie and to determine those land treatment practices which, if applied, could most significantly reduce the pollution from agricultural operations. Through this project we also hope to define those sources of non-point pollution which are not directly related to agriculture, but do exist in an agricultural watershed and need to be reduced, and if possible, eliminated.

This project represents a multi-agency, multi-disciplinary approach to the total problem of non-point source pollution in agricultural areas. It involves demonstration through a program of accelerated land treatment applied on private lands with assistance from the Soil Conservation Service, applied research by Purdue University, with leadership and administration by the Allen County Soil & Water Conservation District. It requires the cooperation from a very diverse group of federal, state and local agencies as well as private landowners.

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[1] Allen County Conservationist in charge of directing the "Black Creek Study" Environmental Impact of Land Use on Water Quality for the Allen County Soil & Water Conservation District.

After completing four years of this five year study, we have obtained some very interesting results, and we have also verified some assumptions that we had only thought to be true in the beginning. The scientific investigators that the district has contracted with to do the research in the watershed will be presenting detailed information about results obtained in the project in other papers to be presented at this seminar, therefore, I will only discuss the land treatment aspects of the program and how it might affect future district programs.

First, I think it is significant that we were able to sign cooperative agreements with 95% of the landowners in the watershed. A cooperative agreement simply means that the landowners we contacted were interested enough in knowing what was available through the project that they signed an agreement asking for the technical assistance to survey and design measures that could be applied on their land. Only 5% of the landowners in the watershed were unwilling to venture this far. Over 80% of the landowners in the watershed have signed a legal contract with the district for the application of land treatment practices on their farms. The contracts simply state that the landowners will install the needed erosion control practices as outlined on their contract and that the district will supply the cost-share incentives and technical assistance as stipulated on the contract. Cost-share incentives on the practices averaged 70% for all the practices applied. At the end of four years of application a little over 57% of the watershed has been adequately treated with erosion control measures. The district has spent approximately four hundred and forty-four thousand dollars as of September 30, 1976 for payment to landowners applying practices. We began this study with the feeling that we should offer all presently known conservation practices to the landowner with cost-sharing. There were thirty-one practices recommended by the Soil Conservation Service which were adopted by the Black Creek Study when it began. Our district feels that we have learned through these last four years that it would not be feasible to cost-share on all thirty-one practices as we have in this study if we were to apply them on a larger area in the future.

In evaluating the practices our district can only justify the expenditures on less than ten practices relative to the goals of erosion control and improved water quality. We will attempt in the last year to further define those practices and relate their use to improved water quality. Through this process of elimination we are going to be able to realistically define best management practices for water quality improvement in the Black Creek Study. In looking at the cost summary for land treatment, (Table #1) note that if the total dollars spent for land treatment and payment to SCS for technical assistance is applied to the acres adequately treated in the watershed the cost runs over one hundred dollars per acre. One does not have to figure very long before he realizes it is not feasible to consider a non-point pollution program on a national scale that involves costs at that level. However, if we define the best management practices the costs could be significatnly reduced. In evaluating cost sharing for best management practices we really have to use the philosophy of public dollars for public benefit, and therefore, we have to concentrate on those practices which are necessary for erosion control and improved water quality. We also have to consider those practices which are permanent so that the public can be assured that the practices will remain on the land for a long period of time, even with land ownership changes.

COST SUMMARY FOR LAND TREATMENT
Black Creek Study
September 30, 1976

	UNIT	ACCOMPLISHMENT	TOTAL COST	UNIT COST
Total incentive payment for acres under contract	Ac.	10,795	444,702.89	41.20
Technical assistance costs for acres under contract	Ac.	10,795	183,432.87	16.99
Total cost of land treatment including technical assistance on acres under contract	Ac.	10,795	628,135.76	58.19
Total incentive payments for acres adequately treated	Ac.	5,986	444,702.89	74.29
Cost of technical assistance for acres adequately treated	Ac.	5,986	183,432.87	30.64
Total cost for land treatment including technical assistance for acres adequately treated	Ac.	5,986	628,135.76	104.93

NOTE: District cost share for all practices averaged 70%

Ideally, practices that meet these requirements can be called best management practices. One definition for best management practice would be those that provide maximum erosion control, maximum economic return to the landowner and allows for maximum production. Of course it is very difficult to find that combination in the "real world". Therefore, for example, if a best management practice is needed for erosion control and improved water quality but will reduce economic return and production for the landowner, we must recognize that the lost revenue and lost production must be compensated for through some means such as financial incentives. We can determine how great the financial incentive must be, based on how much production has been lost, how much economic value has been reduced and thirdly, by the farmers reaction to installing the practice on their farms.

From our experience on the project to date,of the thirty-one practices originally outlined in the work plan, the district would recommend these best management practices: The first best management practice which is very significant to Black Creek and many areas of the country is Conservation Tillage and within conservation tillage you gain proper crop residue management. The second would be Parallel Tile Outlet Terraces. In order for terraces to be installed other practices must be incorporated in the terrace plan and are really required by the terrace system; these would be conservation cropping system (crop rotation), tile drainage and contour farming. The third practice is Pasture & Hayland Planting. Some areas are critical enough that they need to be removed from crop land and placed in permanent pasture. Another "BMP" would be Animal Waste Holding Ponds and Tanks. Included in this practice area would be any management facility which would control runoff of animal waste into public waterways. Other best management practices would include: Grade Stabilization Structures, Grass Waterways, and Sediment Control Basins where needed. The last category of best management practices would be those practices related to the streams, which are: Streambank Protection, Streamchannel Stabilization, and Field Border establishment. The other practices listed in the original work plan can be considered on a complete conservation plan for a land unit but we feel should not be assisted with public dollars because there are not sufficient public benefits to justify public funding. Another point that needs to be made is that the more practices you have included in a legal contract the more difficult a land treatment program becomes to administer. This is a point that needs to be looked at very carefully. There needs to be less emphasis on getting numbers for progress reporting purposes and more emphasis in getting acres under proper erosion control through the installation of the best management practices.

The cost data prepared and attached on table #2, certainly bare out that the landowners reacted consistantly with what I have pointed out. They have installed only those practices they could recognize as being needed and important. If you will add up the dollars spent by the district for financial incentives as I have, it shows that of the four hundred and forty four thousand dollars spent for cost-sharing on land treatment practices, four hundred and two thousand of that was spent on the best management practices listed previously. That means that only a little over forty-two thousand was spent on the other seventeen practices. If you will note the accomplishments on the other seventeen practices you can see why few dollars were spent. For many of them there has been no accomplishment at all in four years. These figures are significant. If we really want to concentrate

PROGRESS REPORT - LAND TREATMENT

Black Creek Watershed
September 30, 1976

ITEM	UNIT	PROJECT GOALS	ACCOMPLISH-MENT	PER-CENT GOALS	AMOUNT OF DISTRICT COST-SHARE	DISTRICT UNIT COST	PER-CENT COST
District Cooperators	No.	148	141	95%	N/A	N/A	N/A
Conservation Plans	No.	170	133	78%	N/A	N/A	N/A
Contouring Farming	Ac.	769	0	0%	0	N/A	80%
Land Adequately Treated	Ac.	10,573	5,986	57%	N/A	N/A	N/A
Conservation Cropping System	Ac.	7,418	5,621	76%	4,035.60	0.56	70%
Critical Area Planting	Ac.	10	15	150%	2,752.57	183.50	65%
Crop Residue Management	Ac.	7,491	1,149	15%	2,159.60	1.87	70%
Diversions	Ft.	39,200	1,750	4%	1,222.31	0.70	75%
Farmstead & Feedlot Windbreak	Ac.	75	4	5%	289.70	72.42	70%
*Field Border	Ft.	288,320	102,809	36%	24,678.76	0.24	70%
Field Windbreak	Ft.	12,000	0	0%	00	N/A	70%
*Grade Stabilization Structure	No.	368	138	38%	71,900.36	521.02	75%
*Grassed Waterway or Outlet	Ac.	68	62	91%	33,004.95	532.33	80%
*Holding Ponds & Tanks	No.	11	7	64%	16,711.08	1,387.30	50%
Land Smoothing	Ac.	300	0	0%	0	N/A	70%
Livestock Exclusion	Ac.	215	22	8%	7,772.68	353.30	80%
Livestock Watering Facility	No.	28	2	7%	864.50	432.25	70%
*Minimum Tillage	Ac.	7,656	291	4%	1,550.80	5.32	80%
Pasture & Hayland Management	Ac.	402	97	24%	374.40	3.85	65%
*Pasture & Hayland Planting	Ac.	501	30	6%	4,462.72	148.76	70%
Pond	No.	39	9	23%	10,827.66	1,203.07	60%
Recreation Area Improvement	Ac.	12	9	75%	549.29	61.03	50%
*Sediment Control Basin	No.	6	3	50%	4,448.90	1,482.97	70%
*Stream Channel Stabilization	Ft.	6,000	9,900	166%	95,673.53	9.57	80%
*Streambank Protection	Ft.	122,000	74,100	61%	51,424.74	0.69	70%
Stripcropping	Ac.	300	0	0%	0	N/A	80%
Surface Drains	Ft.	90,000	200	1%	408.54	2.04	65%
*Terraces	Ft.	22,000	41,612	189%	26,714.85	0.64	90%
*Tile Drains	Ac.	200,300	63,599	32%	81,703.98	1.28	70%
Tree Planting	Ac.	10	0	0%	0	N/A	70%
Wildlife Habitat Management	Ac.	222	148	67%	1,171.37	7.91	60%
Woodland Improved Harvesting	Ac.	200	0	0%	0	N/A	65%
Woodland Improvement	Ac.	610	0	0%	0	N/A	70%
Woodland Pruning	Ac.	50	0	0%	0	N/A	70%

*Best Management Practices in Black Creek Watershed on getting land treatment on the eroding agricultural acres then we need to go with the best management practice approach and eliminate all the frills. As a result, the cost of technical assistance and administration would be reduced significantly, and that is very important, because those costs are all overhead to the taxpayers.

At this point, I would like to go into a somewhat detailed explanation of how I feel, from the experience gained on this project, that we can apply best management practices nationally in a way that it can be both economically feasible and acceptable to society as well as an implementable approach to applying best management practices." Keep in mind that this is only my opinion, however through my discussions I feel that there are many people who agree. First, I think the institutional structure must be supported at the federal level and implemented at the local level. As we know, congress has passed Public Law 92-500 and has mandated the U.S. Environmental Protection Agency to carry out that law. In the area of non-point pollution relative to agricultural operations I feel that EPA needs to spell out the requirements of the law and ask that each state provide it with guidelines as to how non-point pollution control for agricultural sources will be controlled in that particular state. This is consistant with the 208 planning approach. The state then, or an agency thereof, needs to rely on the Soil & Water Conservation Districts throughout that state to use the states guidelines and within them select those best management practices that apply to their particular district.

It is not feasible to select best management practices at any level higher than the local SWCD, simply because the practices vary with location. For example, it is obvious that a best management practice in Washington County, Wisconsin, is stripcropping on the contour, however in the Black Creek Watershed, Allen County, Indiana, stripcropping is not feasible. After the district has spelled out the best management practices for its county the state must provide the district with funds to provide financial incentives for installation of the best management practices that meet the guidelines of the state. The state hopefully will be able to obtain the funds for this use from the federal government, or at least a portion of them. When the district is provided with money it can proceed with working with landowners to install best management practices for land treatment with cost sharing and technical assistance.

The Soil Conservation Service will still be needed to provide the technical assistance to the district, however the district will require that the assistance is provided for the application of best management practices first. If the Soil Conservation Service wishes to apply other practices they will continue to do so, however it would be a very low priority with the district and there would be no cost-sharing. Contacts by the district to the landowner for needed best management practices would be made as the result of requests by the farmers or by complaints by other taxpayers. The application of these practices would be based on the district's availability of funds and technical assistance. The priorities would be placed on those requests which seem most serious to water quality and application assistance would be provided there first.

In all reality, however, the application of best management practices to the level necessary for water quality improvement will not be accomplished on a totally voluntary program. Enforcement will be needed on a small percentage of the landowners. In order to be sure that best management practices are installed properly and at the amount necessary for erosion control in the county it will be necessary for the state agency to provide enforcement when requested by the district. It would be the district's obligation however to submit a written request to the state agency for its assistance in seeing that enforcement is properly carried out when needed. This, however, would not be direct enforcement but would come about as the result of the district informing the landowner that if he does not cooperate with the district and install the needed practices the state will come down on him with enforcement measures such as fines, etc. Using this approach there will probably be very few cases where the district will be unable to obtain cooperation for proper application of practices. However, I would estimate that there are approximately five percent of the landowners who will not react to anything less than enforcement.

If all of this is to come about, and in reality be a implementable program, the first thing that must be recognized is that Soil & Water Conservation Districts do need to hire professional district representatives to assist them with management. By this I mean the local soil and water conservation district supervisors must have an executive secretary who is a professional, qualified to manage their programs. This needs to be someone who is in the district office day by day and knows what is happening and can inform the supervisors of the local needs and problems. Supervisors have to rely heavily on the information that they receive at the monthly board meetings. At the present time, in most districts, the only form of information that supervisors receive is that supplied to them by the District Conservationist. The District Conservationist is a federal employee of the U.S.D.A. Soil Conservation Service and must represent that federal agency. Therefore, the supervisors are only informed of those things that are in the best interest of the federal government, Many times that is in the best interest of the supervisors as well, however, what is important is there are times when that is not so. For example, supervisors are not directly concerned about how many visits the D.C. has made with landowners, or the number of groups he has spoken to, or the number of times he has visited the county plan commission, or whether the district office complies with the new "open space" concept for the U.S.D.A. Service Centers. Supervisors are only directly interested in how much application of erosion control practices has been and is being accomplished in their district. Therefore, if we get into administering the application of best management practices on agricultural land, it will be important that the district's executive secretary see to it that priorities are kept day to day. For example, it will be more important that all requests for information and application relative to installing best management practices be dealt with before we become concerned with working with some urbanite to develop wildlife habitat management, a back yard pond, or tree planting on their ten acre spread. There are other service agencies as well as private consultants available to do this.

A district professional will also be needed simply to follow up on requests and complaints of erosion control problems where best management practices might be needed and to handle the enforcement procedures when necessary. In terms of handling the cost-share money needed to install best management practices, it could be done either of two ways. My first choice would be that the district receive and administer funds themselves.

In the Black Creek Study we have proven this to be a very efficient means of handling cost-share dollars. The district knows what the top priorities are for funding because they are involved in the planning and technical needs determination by the Soil Conservation Service. The other alternative would be to allow the Agricultural Stabilization and Conservation Service (ASCS) to handle the cost-share dollars. This agency is already set up to handle cost-share monies as they have for years in the ACP program. However, if the decision would be to use ASCS it would be very important that the district have more involvement and authority as to how the funds are spent. It is only logical that since the district and its technical staff from SCS will be reviewing the needs and preparing the technical plans for establishing best management practices, that they would have the best knowledge as to what requests should be funded and at what level. Many times in the history of the ACP program, funds have been allocated with very little knowledge of the work and effort already encountered by the district and SCS or the severity of the problem considered for funding. This situation could not be tolerated in the type of non-point pollution control program needed in the future. If the history of the ACP programs can be used as an example, it is obvious that ASCS would involve more staff and more dollars in administering the funds for installing best management practices than the district would need. As the case is with most everything, the more people you involve the less efficient you become. However, with some changes, ASCS could handle this phase of the program, someone else will need to make that determination.

In summarizing this whole approach, the most significant thing that must be remembered, is that we cannot afford to loose tract of the "grass roots" contact and understanding that the local soil and water conservation districts have with its agricultural landowners. There is no way that a federal agency or even a state agency will be able to have an effective non-point pollution control program without involving the local soil and water conservation districts. Farmers are willing to do all they can when they understand and the districts do have an understanding with farmers simply because the districts are supervised mostly by farmers.

If this link is ever broken, we will be in for serious problems. If an effort is made to enforce land treatment controls on farmers without their understanding, the problems will be much greater than anyone in government realizes today. "You cannot control erosion by sentencing all the farmers to jail, or the bailiff will get hungry." It is very important that some real serious long term thinking be done as to how the non-point agricultural pollution problems will be handled. The approach that I have outlined, I am confident is a workable approach and an implementable one. I'm sure that I do not have a perfect plan; it does need some additional thought and there are probably changes needed in many parts of the proposed program. However, I think the concept is very sound, I also believe that the example that has been demonstrated by the Black Creek Study, not only in how a local district can administer the installation of practices on private landowners, but also how farmers are willing to cooperate by installing best management practices, is a testimony to the plan I propose.

This project also points out the need for some type of soft enforcement if we hope to accomplish an effective non-point control program. Soil and Water Conservation Districts throughout the country want to be part of planning for non-point pollution control. Anyone involved in 208 programs should definitely consider getting the local SWCD involved if they have not already done so. The project also points out that soil and water conservation districts are going to need to make some changes to meet the challenges of non-point pollution control in the future. The most important change would be the district's hiring an executive secretary for each soil and water conservation district. The supervisors cannot be expected to take on a project of the proportion that non-point pollution control on agricultural lands involve without some staff of their own. Also, the Soil Conservation Service and the Cooperative Extension Service must recognize that this change is needed if we are to enter a program of this nature. I know there is reluctance in some parts of these agencies to such a change, however those who will look into the future with an open mind will recognize that the effectiveness of both the Soil Conservation Service and the Cooperative Extension programs would be enhanced by the district's becoming self-sufficient. "We no longer can afford to look back at the problems of the past; we must instead look ahead at the challenges of tomorrow."

SOCIAL FACTORS THAT INFLUENCE PARTICIPATION IN SOIL CONSERVATION: BLACK CREEK PROJECT[1]

by

David L. Taylor and William L. Miller[2]

One of the most important tasks that faces any program designed to influence or alter the social behavior of a group of people is how to attain the cooperation and participation of those people. This is absolutely necessary if the project is going to achieve its goals without coercion and/or creating an unfavorable image among those persons.

In the Black Creek Project, farmers are being encouraged to adopt agricultural management practices on their farms which benefit society by reducing the runoff of sediment and nutrients which pollute streams and lakes. To achieve this objective economic incentives have been combined with information designed to encourage the farmer to adopt management practices to reduce runoff. To personnel involved with this project who have worked with the farmers, it has been apparent that the adoption of a particular management practice varies between farmers and groups of farmers in the project area.

Previous reports have emphasized achieving cooperation and participation by working within the local social structure particularly in the Amish community [1]. The need for this was verified by the different attitudes toward the project held by leaders in comparison with other farmers in the project area.

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[1] This research was financed in part by EPA grant No. G005103.

[2] The authors wish to thank Joe Donnermeyer for his comments on this paper. The authors are Graduate Research Assistant in Sociology and Professor in Agricultural Economics, respectively.

This paper builds on the previous research and utilizing recently available data rigorously analyzes the relationship of social factors to the adoption of the new management practices. The statistical technique utilized for this analysis is the path analytic procedure. This technique permits the assessment of the relative importance of each factor on the subsequent adoption or rejection of the new management practice.

The objective of this research is to determine which factors are most important for adoption of the management practices. In addition, it will determine at what stage in the decision making process these factors exert their major infuuence on the behavior of the farmers.

This paper is divided into three additional sections. The next section examines the theoretical basis for the model which is based on previous sociological research on the diffusion of innovations. The following section examines the results of the path analytical model. The last section indicates conclusions and policy implications derived from the analysis.

THEORETICAL FOUNDATION

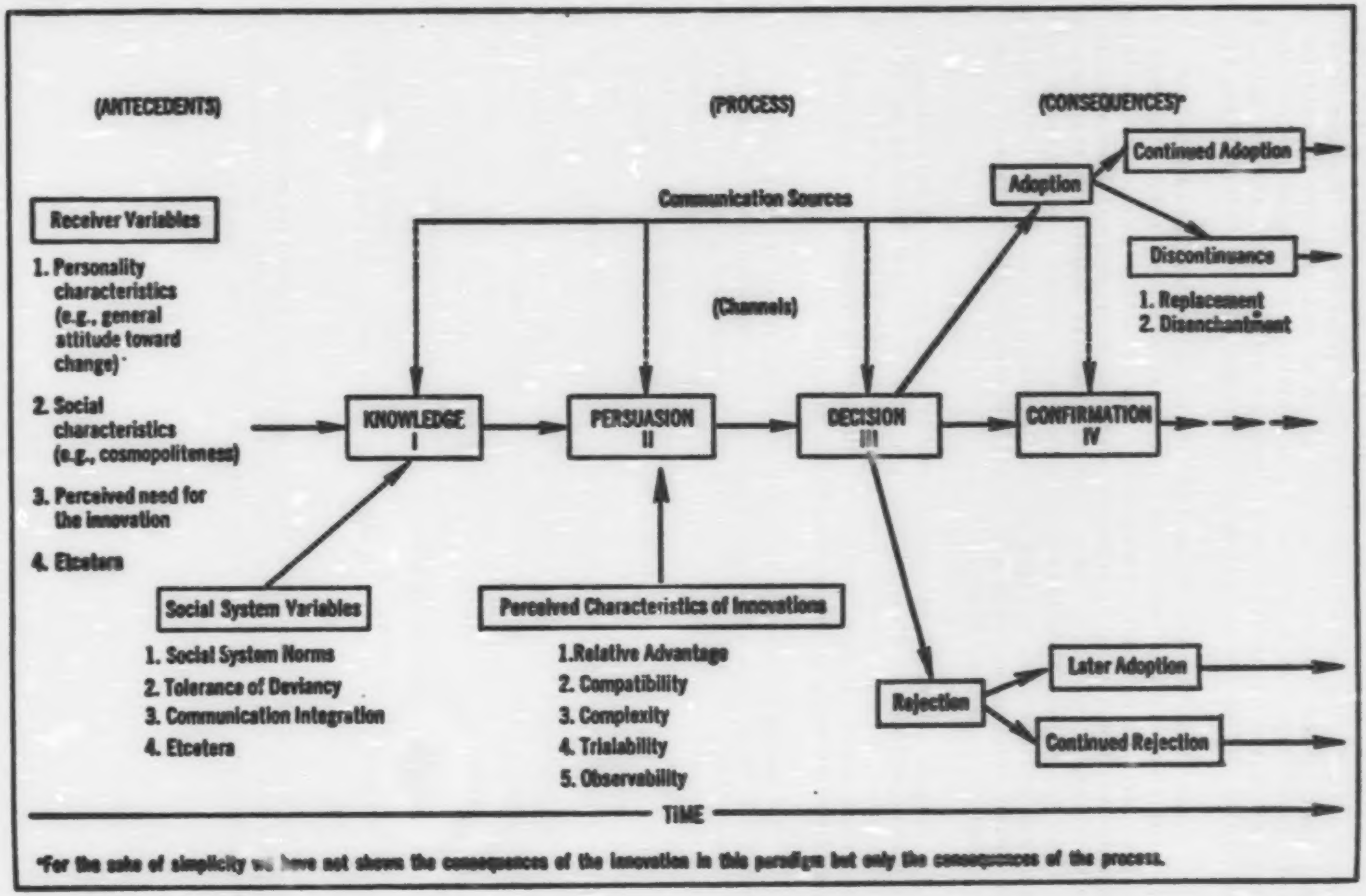
The Rogers and Shoemaker Theoretical Model

The assumption that adoption is the result of a social or psychological process has been evident in virtually every study of adoption behavior. However, there has, in general, been little agreement regarding how many stages are involved in this process.

> For instance, Wilkening [2] and Emery and Oeser [3] utilized a three-stage process. Wilkening [4] proposed four stages, as did Ryan and Gross [5] and Rakim [6], Beal and others [7] and Copp and others [8] used five stages. Lavidge and Steiner [9] postulated six stages while Singh and Pareek [10] proposed an eight stage model. [11]

The theoretical model of the innovation-decision process utilized to study adoption of management practices in the Black Creek Watershed is presented in Figure 1. This model was developed by Rogers and Shoemaker [11]. They propose that their model accounts for the criticisms of earlier models, is logically consistent with the learning process (in the conventional S-R conceptualization), and follows Hovland's [12] model of attitude change. [11]

As Rogers and Shoemaker [11] describe it, their model contains three major divisions: (1) Antecedents, (2) Process, and (3) Consequences. "Antecedents are those variables present in the situation


(ANTECEDENTS)
(PROCESS)
(CONSEQUENCES)*
Receiver Variables
1. Personality characteristics (e.g., general attitude toward change)
2. Social characteristics (e.g., cosmopoliteness)
3. Perceived need for the innovation
4. Etcetera
Social System Variables
1. Social System Norms
2. Tolerance of Deviancy
3. Communication Integration
4. Etcetera
Communication Sources
(Channels)
KNOWLEDGE I
PERSUASION II
DECISION III
CONFIRMATION IV
Perceived Characteristics of Innovations
1. Relative Advantage
2. Compatibility
3. Complexity
4. Trialability
5. Observability
Adoption
Continued Adoption
Discontinuance
1. Replacement
2. Disenchantment
Rejection
Later Adoption
Continued Rejection
TIME

*For the sake of simplicity we have not shown the consequences of the innovation in this paradigm but only the consequences of the process.

Figure 1. The Rogers and Shoemaker Theoretical Model.

prior to the introduction of the innovation. Antecedents consist of: (1) the individual's personality characteristics, such as his general attitude toward change, (2) his social characteristics, such as his cosmopoliteness, and (3) the strength of his perceived need for the innovation." The authors group the above antecedents together in a category called "Receiver Variables." A second category of antecedents is referred to as "Social System Variables." These include the relevant norms of behavior (e.g., modern and traditional) the group's tolerance for deviancy, the amount of communication integration, etc.

Also affecting the Innovation-Decssion process is amount and type of communication which the individual receives about the innovation. Sources of such communication can be both formal, such as change agents and the media, or informal such as interpersonal communication with friends, relatives, etc. One may readily infer from the diagram of the Rogers and Shoemaker [11] model--see Figure 1--that these Antecedents are directly related to the Knowledge stage of the Innovation-Decision process,and only indirectly related to later stages in the process through this stage.

Specifically, Rogers and Shoemaker [11] propose a four-stage process, consisting of (1) initial knowledge of the innovation, (2) persuasion, or the formation of attitudes toward the innovation, (3) decision about whether to adopt or reject the innovation, and (4) confirmation seeking about the decision made.

The Knowledge stage is where the individual is initially exposed to innovation's existence and gains some understanding of how it functions. There is some uncertainty regarding whether the individual becomes aware as a result of his active seeking of knowledge, or as a result of the efforts of others to bring the Knowledge to him [13]. However, since the situation discussed in this paper is one wherein the individuals are clearly passive receivers of the knowledge of the innovations, this issue is unimportant.

Rogers and Shoemaker [11] also discuss the relationship between the Knowledge stage and the Decision stage. They note that "most individuals know about many innovations which they have not adopted." This may be because the individual does not regard them as relevant or useful, or there may be monetary or social constraints which prohibit him from adopting them. Thus, Rogers and Shoemaker propose that the Knowledge stage has no direct relationship with the Decision stage, due to the intervention of attitude formation, and other constraints.

To summarize, the Knowledge stage is the first stage of the Innovation-Decision process. It is the link between the Antecedent variables and the second, Persuasion stage of the process.

The persuasion stage is simply the stage at which, after gaining knowledge of an innovation, the individual forms a favorable or unfavorable attitude toward it. "Whereas the mental activity at the Knowledge stage was mainly cognitive (or knowing), the main type of thinking at the Persuasion stage is affective (or feeling)." [11] The temporal sequence here is logically correct, in that an individual cannot form an attitude toward something with which he is not familiar. Additionally, this conception of attitudes as intervening between knowledge and behavior is supported by research and theory in social psychology [14].

The relationship of the Persuasion stage to the third, Decision stage, is discussed by Rogers and Shoemaker [11] in terms of attitude-behavior consistency. They point out that logically a person's attitudinal position should be positively related to his subsequent overt behavior regarding the attitude object. However, they recognize that the correspondence between attitudes and behavior is seldom perfect, and may even be quite low. They cite the classic study by LaPiere [15] and others (e.g. Festinger,[16];Rokeach,[17]) where attempts were made to explain low correlations between attitudes and behavior.

Thus, Rogers and Shoemaker [11] propose that there will be a direct, positive relationship between attitudes and the decision to adopt. However, they appear to believe that this relationship may not be particularly large due to constraints which may affect the person's overt behavior. (See McGuire[14] for further discussion of this issue.)

The Decision stage, as Rogers and Shoemaker [11] describe it, consists of the individual's initial decision to adopt (or at least try) the innovation. This is the stage which measures the success of the Black Creek project because the objective of the project is to encourage farmers to adopt management practices which improve water quality. Since the final stage of confirmation is not presently important to the analysis of the Black Creek situation, it will not be discussed further.

Black Creek Theoretical Model

The appropriate variables to measure the participation of farmers in the Black Creek Watershed were selected on the basis of the Rogers and Shoemaker [11] model and other appropriate theoretical and empirical research on the adoption of new technology. The variables are identified in Figure 2 in a format similar to the Rogers model. The specific reasons particular variables were selected and a detailed description of these variables are presented below.

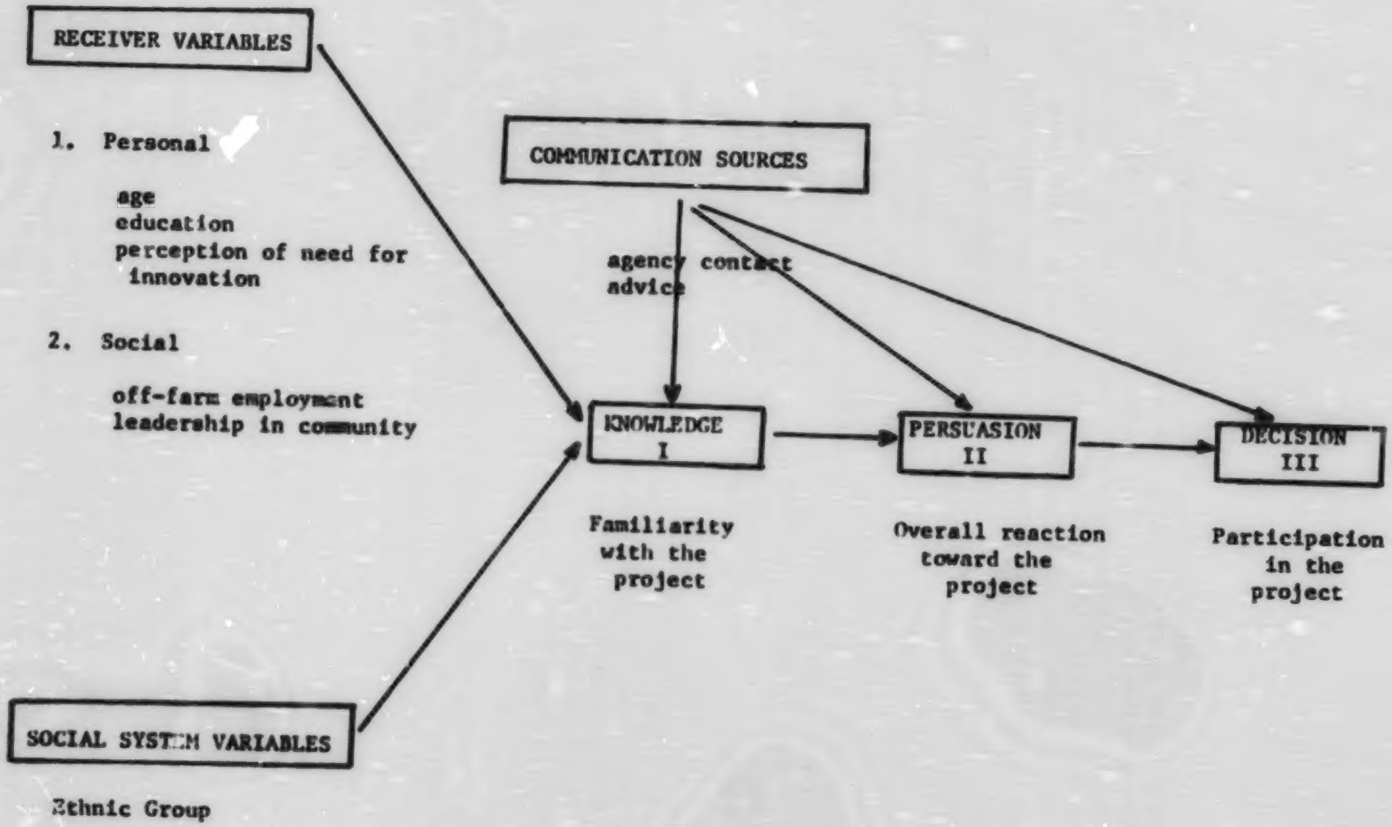

RECEIVER VARIABLES
1. Personal
age
education
perception of need for innovation
2. Social
off-farm employment
leadership in community
SOCIAL SYSTEM VARIABLES
Ethnic Group
COMMUNICATION SOURCES
agency contact
advice
KNOWLEDGE I
Familiarity with the project
PERSUASION II
Overall reaction toward the project
DECISION III
Participation in the project

Figure 2. The Black Creek Theoretical Model.

The age of the farmer has been shown to be related in various ways to adoption behavior in different studies. Age has been found to be positively related [18], negatively related [19], and unrelated to the adoption of innovation[20].

In this model, it is hypothesized that age is negatively related to adoption of the pollution control practices, since there are a number of older, more traditional farmers in the community. Additionally, most of the Amish farmers are older, this should also contribute to the negative relationship between age and adoption.

Education of the farmer has been found to be related to adoption behavior in numerous studies. Most of these studies (e.g. Kivlin [18]) have found it to be **positively** related to adoption, this is the type of relationship proposed in the present model.

Whether the person has additional, off farm employment has also been found to be related to adoption, in the sense that it indicates a non-subsistence or commercial orientation on the part of the farmer. This has been shown by Beal, et al. [19] and Reddy & Kivlin [21] to be positively related to the adoption of innovation. This is precisely the form of relationship expected in this study.

Another measure related to the adoption behavior is the farmer's leadership in the community (Arndt,[20]; Loomis,[22]). In this study leadership in the community, measured sociometrically, is proposed to be related positively to adoption behavior.

Rogers and Shoemaker [11] note that the three social system variables most relevant to the adoption of innovation are: (1) social system norms, (2) tolerance of deviance, and (3) communication integration. Because the area of study contains a number of Amish farms (31) as well as a number of conventional, small and large farms (termed "Non Amish"), the social system variables may be simply operationalized by a dummy variable coded (0) for Amish and (1) for Non Amish. This procedure is supported by the fact that the Amish have a particularly rigid normative structure, low tolerance of deviance from group norms, and high communication integration (e.g. Hostetler,[23]; Kephart, [24]).

Though the specific theoretical model proposed by Rogers and Shoemaker [11] has not been tested prior to the present study, there are some studies which find relationships that are, in general, congruent with those proposed in the model.

For example, the level of education of the farmer has been found to be positively related to early knowledge of innovations (Kivlin, [18]; Roberts, et al.,[25]). Additionally, early knowers of innovations have been found to have greater exposure to mass media, interpersonal communication, and change agents than later knowers (Kivlin,[18]; Beal, et al., [26]; Beal, et al.,[27]). Finally, early knowers also tend to be more cosmopolite than later knowers (Kivlin, [18]).

Communication sources have been found to effect all three stages of the innovation-decision process. Specifically, mass media sources of communication have been shown to be more important at knowledge stage, whereas interpersonal sources of communication are more important at the persuasion stage (Beal and Rogers,[28]; Beal and Rogers, [29]). However, the relative importance which change agent contact plays at the three stages has not been specifically examined. This is one of the purposes of the present study.

The internal consistency of the three theoretical stages has already been discussed. However, it may be reiterated that the stages are consistent with existing literature on knowledge, attitude formation, and behavior in the field of social psychology (McGuire,[14]; Hovland, et al.,[12]).

ANALYSIS

Data Base and Data Collection

The data presented in this paper were obtained as part of a larger project undertaken by Purdue University and several federal, state, and county agencies under the auspices of the Environmental Protection Agency. The Agency selected a watershed of about 12,000 acres along the Maumee River in Allen County, Indiana, because a number of farmers in the watershed had serious erosion problems on their land which were causing major pollution problems in the Maumee River and, ultimately, in Lake Erie. One of the main purposes of the project was to indroduce a number of agricultural innovations to the farmers in the watershed. To measure the impact of the project and the reactions to it, a sample of farmers in the area were interviewed. In January, 1974, a 97 percent sample of all farms 10 acres or larger was interviewed (N = 89). Two years later, in February 1976, 80% of those initially interviewed were reinterviewed (N = 71).

The questionnaire was designed to measure characteristics of the farming operation, as well as various social and psychological characteristics of the farmer, including his attitudes toward pollution, government, and toward the project itself. The specific measurement of the variables included in the study are described below.

Age (AGE) is the actual age in years of the farmer.

Education (EDUCA) is the education of the farmer, coded from (0) - no formal education to (8) some graduate work.

Perception of need for innovation (CSNRPA) is derived from the farmer's response to the statement "Conservation of soil is not a real problem in this area." The fact that this statement is negatively worded means that an "agree" response to this question indicates little or no perceived need for soil conservation innovations and related practices. This was scored (1) for agree and (2) for disagree.

Off farm employment (EMPLOY) is a dichotomous variable indicating whether or not the farmer has additional off-farm employment.

Leadership score (LEADER) is the actual number of sociometric choices the farmer received when respondents were asked who was a well-respected farmer in the area.

Ethnic Group (ETHGRP) is a dichotomous variable which indicates whether the farmer was Amish or Non-Amish.

Agency Contact (AGENCYCT) is an index of the amount of contact the farmer has had with each of the agencies involved in the project. Each agency is coded from 0 - no contact, to 3 - contact 3 or more times. The scores for each agency are then summed to yield a total score for each farmer.

Advice from Leader (ADVICE) indicates whether the farmer had sought advice about farming practices from the person he selected as a well-respected farmer--used here as "LEADERS", the variable operationalizing community leadership.

Familiarity with the project (BCDP) is a dichotomous variable indicating whether the farmer had had contact with project personnel as of January, 1976.

Overall reaction toward the project (FAVOR74) is the farmer's attitude toward the project in 1974. It is scored from 1 to 5, with 5 being very favorable.

Participation in the project (PARTBCP) indicates whether and how much the farmer has participated in the project as of February 1976. It is scored 0 - none, 1 - a little, 2 - very much.

The Statistical Model

The path analytic technique was selected to analyze the relationship among the factors identified in the Black Creek theoretical model. Considering the current debate regarding the possibility of misplaced precision in the use of path analysis for sociological research (Coser[33]; Featherman,[34]; Treiman [35]), as the skepticism voiced by Miller and Stokes [36] over the technique's applicability to rural sociological issues, it is particularly important that the use of such sophisticated statistical procedures be well-justified.

First, by considering the three stages of the Innovation-Decision process to be a causal chain of three endogenous variables, path analysis will allow the relative effect of the exogenous or antecedent variables on each stage of the process to be assessed, even though the variables are measured in different units. It allows one to control for the effects of all other variables, so each variable's independent effect may be measured.

Second, this property of path analysis is important because it enables a test of the hypothesis of Rogers and Shoemaker [11] that Antecedent variables have direct effects only on the Knowledge stage of the process. This same property also enables a test of their hypothesis that formal sources of communication affect mainly the Knowledge stage, whereas informal communications mainly affect the later stages. Since the division between the effects of the two forms of communications is not absolute, it is particularly important to have relatively precise measures of the effects of each type, while all other factors are controlled. This will insure that the correlation is not due to relationships among other variables in the system.

The theoretical model which has been proposed is analyzed with regression analysis of three separate structural equations. First, as mentioned above, participation in the Black Creek Project (PARTBCP) is regressed on favorability toward the Black Creek Project in 1974 (FAVOR74), amount of contact with government agencies involved in the project (AGENCYCT), the farmer's familiarity with the Black Creek Project in 1974 (BCDP) and then on the various receiver variables and the variables operationalizing the communication between the farmer and local leaders and government agencies. Additionally, PARTBCP is regressed on the relevant social system variable of whether or not the farmer was Amish.

In the second equation, the farmer's favorability toward the Black Creek Project in 1974 is regressed on BCDP and on the exogenous background variables. The third equation consists of the regression of the farmer's familiarity with the BCP on the exogenous variables.

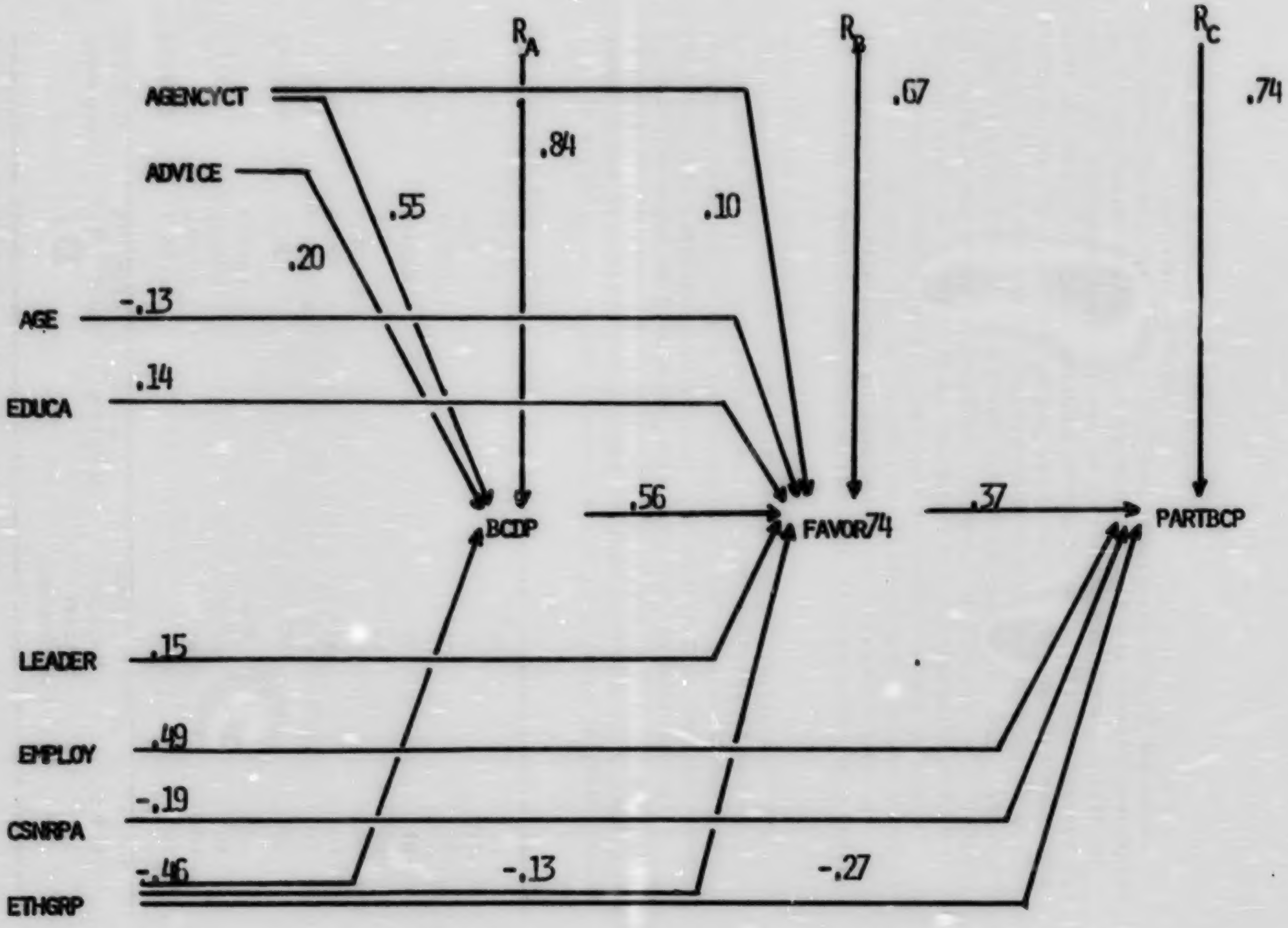
In developing this model of participation in the project, the parameters of each of the three equations have been estimated by ordinary least squares (Land,[30]). These regression coefficients indicate the direct effect that an independent variable had on a dependent endogenous variable with the effects of the other variables appearing in that equation controlled. In Table 1 the numbers in the far right column are the standard errors for the regression coefficient. The multiple correlation coefficient is shown in the second column (Anderson,[31]).

Table 1. The Results of the Path Analysis.

Dependent variable	Independent variable	Multiple R	Standardized partial regression coefficient	Standard error
PARTBCP	FAVOR74	.67	.37	.09
	EMPLOY		.49	.08
	ETHGRP		-.27	.08
	CSNRPA		-.19	.09
FAVOR74	BCDP	.74	.56	.09
	AGENCYCT		.10	.11
	EDUCA		.14	.09
	LEADERS		.15	.09
	AGE		-.13	.08
	ETHGRP		.08	.10
BCDP	AGENCYCT	.56	.55	.10
	ETHGRP		-.46	.11
	ADVICE		.20	.10

In a few instances the standard error is relatively large compared to the regression coefficient. These variables have been retained in the equation when necessary to retain congruence with the theroetical model of Rogers and Shoemaker [11] or when empirical evidence supported their inclusion. The statistical justification for this procedure is that the omission of such variables results in an error in the specification of the equation, and in biased estimates of the coefficients of those variables included in the equation (Kmenta, [32]).

Figure 3 depicts the hypothetical causal relationships between the variables. This model is diagrammed in accordance with the stages or functions of the Innovation Diffusion process presented by Rogers and Shoemaker [11]. This path analytical model indicates linear, additive relationships among the set of variables that are included in the model. The eight variables at the left are considered to be exogenous. The three remaining variables, BCDP, FAVOR74, PARTBCP, are considered to be endogenous, and thus completely determined by the variables in the model and by the residual variables (R_a, R_b, and R_c). These residual variables represent the effects of all other variables not included in the model that cause variation in an endogenous variable. It is assumed that the residual variables are uncorrelated with each other, and uncorrelated with any other variables in the same equation.



R_A
R_B
R_C
AGENCYCT
ADVICE
AGE
EDUCA
.84
.67
.74
.55
.20
.10
-.13
.14
BCDP
.56
FAVOR74
.37
PARTBCP
LEADER
.15
EMPLOY
.49
CSNRPA
-.19
ETHGRP
-.46
-.13
-.27

Figure 3. The Path Analytic Model with Standardized Partial Regression Coefficients.

Analysis of the Structural Model

In general, this structural model indicates that there is a distinct applicability of Rogers and Shoemaker's [11] model of adoption behavior to the present data. First, using several of those variables which Rogers and Shoemaker indicate are important factors in the process, it was possible to explain 45 percent of the variance in PARTBCP. Second, in accordance with the theoretical model, several antecedent variables did not have a direct effect on PARTBCP, but instead had only indirect effects on this variable through BCDP and FAVOR74.

Third, the fact that BCDP explains much of the variance in FAVOR74 and FAVOR74 explains much of the variance in PARTBCP validates the important role that knowledge plays in the formation of favorable attitudes, and the importance which these attitudes play in the develppment of participation on the part of farmers through the adoption of agricultural innovations which are proposed by the project.

Specifically, the measure of participation through innovation--PARTBCP--was regressed upon four variables: FAVOR74, EMPLOY, ETHGRP, and CSNRPA. The combined direct and indirect effects of these variables explained 45 percent of the variance in PARTBCP.

Though the farmers' attitudes toward the project and the innovations it proposes have a large positive effect on the farmer's decision to participate, an even larger effect is that of the farmer's employment status. That is, farmers who are employed off the farm are more likely to participate in the project than those who work solely on their farm. One way this may be explained is that this is a measure of cosmopoliteness in the sense that farmers who work off the farm have greater contact with other persons with a wide variety of attitudes. Also, farmers with additional employment are likely to work in business or in industry (these were the most common responses to the question of where they were employed), and both of these fields feature extensive utilization of technology and innovativeness. Thus, such persons would have had more contact with social and technological change than farmers working only on their farm. Another dimension of this relationship is illustrated when the relationship with ETHGRP is considered. This relationship indicates that Amish farmers are more likely to have high participation through innovation than the Non-Amish. This is consistent with EMPLOY since EMPLOY is negatively correlated with ETHGRP. This means that Amish farmers are more likely to have additional employment than are Non-Amish farmers. Given this relationship, the positive correlation between off farm employment and participation becomes even more important. Since traditionally Amish are conservative and opposed to innovation, it is interesting to note that those Amish with off farm employment are more likely than other groups to participate in the project.

Applicability of the Model

Undoubtedly the major advantage of using the Rogers and Shoemaker [11] model as the theroetical basis for the organization of the data is that it illustrates very clearly the fact that developing any sort of public involvement and participation is a process, which goes through several stages before the question of whether or not to participate (and, if so, how much) is finally resolved.

To those involved with the farmers personally over the past few years, this must be quite apparent. First, it is necessary to meet the farmers, to identify themselves, the project, its purposes, its technology, and its concern with planning and improvement of conservation practices. This is the knowledge stage of the model.

Second, the members of the project must demonstrate their technology, and especially their concern for the farmer and his problems through continued contact. Because the technology and methodology proposed by the project are new to many of the farmers, it is particularly important that they have sufficient knowledge and contact with the project. This is important because the attitudes which the farmers hold toward the project should be based on the facts: on the farmers' acquired knowledge of the project, rather than on an arbitrary rejection of the new and an embracement of the traditional. This informed attitude which the farmer develops toward the project is the Persuasion stage of the model.

Finally, after having gained a certain amount of knowledge about the various features of the project, and after having formed attitudes toward the project, the farmer acts on his beliefs. The farmer thus makes a decision whether or not to participate in the project by adopting its technology and practices. Additionally, should the farmer decide that he is going to participate, he must decide to what extent he will participate--how involved he will get in the project. These decisions represent the Decision stage of the model.

CONCLUSIONS AND POLICY IMPLICATIONS

This model has several implications for the Black Creek Project, in terms of understanding the process of developing participation among farmers, and the role that the agencies of the project and informal social relationships play in this process.

To a large extent, the model indicates that agencies play their principal role in simply informing the farmer about the project, the large positive effect of BCDP on FAVOR74 means that farmers who simply know about the project develop a favorable attitude toward it. This is important, because it means that it is not necessary to coerce farmers to participte in the project.

The structural equation model also illustrates the importance of both formal and informal channels of communication play in the innovation-decision process. However, the role of these two sources are not as hypothesized in the Rogers and Shoemaker [11] model. Both formal (AGENCYCT) and informal (ADVICE) sources have their major effect at the Knowledge stage of the process, although AGENCYCT has a minor effect at the Persuasion stage also.

Another important implication of the model is indicated by the important effect of ETHGRP at the Knowledge and Persuasion stages. The model indicates that the Amish are more likely to report a high level of knowledge and participation than the Non-Amish. This is probably due to two factors: (1) The Amish have a very integrated, effective communication system within their community, so that if the project contacts only a few Amish farmers, many of them will know about it in a very short time. This is very different from the situation among the Non-Amish, where farmers tend to know fewer of their neighbors, have less frequent contacts with them, etc. (2) The Amish might also be more likely to have received knowledge of the project early (in 1974) because their land is generally poorer and suffered more erosion problems. Thus, they would have been more likely to have been contacted by project personnel than Non-Amish, who are situated on better land, and had already been using several of the innovations proposed by the project. Thus, the pollution situation among the Amish was in general more critical and required the more immediate attention of the project.

Policy Implications for the Black Creek Project

For the members of the Black Creek Project, this model has several specific implications: (1) Making contact with the farmers (AGENCYCT) in the early stages of the project is very important, because this is when such contact has its greatest impact on the farmer. (2) There are also certain farmers whom it is important to contact first. These are persons recognized as local leaders, persons who have off-farm employment, because they tend to be more cosmopolitan than farmers whose sole source of income is from their farm. (3) Also, since younger farmers with more education tend to be most favorable toward the project, it would be most fruitful to approach these farmers before others, who would be less likely to be as favorable. (4) Another important variable is the farmer's perceived need for the innovation (CSNRPA). Since farmers who see a need for particular agricultural innovations or practices are most likely to participate in the project, these individuals--identified by a survey--should be contacted early in the project. (5) Though not as prominent in this final model, earlier models indicate that the farmers contact with local leaders (ADVICE) plays a small, but significant,role at all three stages of the project. This makes it even more imperative that local leaders be contacted early, since they will be able to spread the information they have obtained. This will give the project and its proposed innovations the additional credence that comes with a highly accredited source of information.

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CONSERVATION TILLAGE TRIALS IN PROGRESS IN THE BLACK CREEK WATERSHED

BY

Donald R. Griffith and Gary W. Carlisle*

Simulated rainfall studies have shown that conservation tillage techniques are quite effective in reducing water runoff, soil loss, and pollutants associated with soil loss. Previous research in Indiana and other Corn Belt states, however, indicates that the various conservation tillage systems are not uniformly adapted in all soil-climate situations.

Factors shown to have a major influence on the success of conservation tillage systems are soil drainage, previous crop, length of growing season, and soil physical properties. Soils in the Black Creek watershed are quite diverse in drainage and other physical characteristics. Cropping sequences also vary greatly. The watershed is in the northern fringe of the Corn Belt and has a shorter growing season than southern Corn Belt areas, where conservation tillage is more popular.

OBJECTIVES

Specific objectives of the tillage trials, listed below, are aimed at reducing soil erosion in the watershed.

1. To determine which conservation tillage systems are adapted on the primary soil types in the watershed. Adapted, in this case, means that the system can be used by farmers of average managerial ability without risk of significant yield reduction.
2. To have conservation tillage techniques in use by a high percentage of farmers in the watershed.

PROGRESS

First Three Years

Original efforts to gain information and promote conservation tillage consisted of farmer comparisons of several tillage systems on several different soil types. Due to unusual weather, nonreplication of the plots, and farmer inexperience with the new techniques, little information was gained during the first three years of the project. However, fall chiseling, with limited secondary tillage in the spring, appeared to be successful with a wide range of soil types and weather conditions.

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Current Activities

It was decided to expand the tillage trial phase of the Black Creek study in 1976. We now control and implement the trials ourselves. The greater uniformity attained should provide more accurate information on which to base tillage recommendations to farmers in the watershed.

Five sites, representing major soils in the watershed, were leased to conduct replicated tillage trials. Tillage systems now being compared include moldboard plowing, chisel plowing, disking, and no-tillage. Comparisons will be made for continuous corn, corn after soybeans, and soybeans after corn. In addition, conservation tillage practices are being demonstrated in other areas by special agreement with cooperating farmers. This information is summarized below.

Table 1. Replicated Tillage Trials, Black Creek Study

Farm	Soils	1975 residue	Number of reps
Shanebrook	Hoytville c. l.	Soybeans	4
Woebbeking	Nappanee si. c. l.	Corn	4
Stieglitz	Whitaker si. l.	Soybeans	4
Shaffer	Haskins l.	Corn	4
	Morley c. l.	Corn	2
Bennett	Morley c. l.	Corn	4

Table 2. Tillage Demonstrations, Black Creek Study

Farm	Soils	1976 crop	1975 residue	1976 tillage
Schlatter	Rensselaer l.	Corn	Soybeans	a. No-till b. Disk
Delagrange	Morley si. l.	Soybeans	Soybeans	Chisel
	Pewamo si. c. l.	Wheat/beans	Soybeans	No-till
Schaefer	Haskins l.	Corn	Sod	No-till

The following equipment has been purchased by the Allen Co. SWCD to implement this new tillage work: J. D. 4020 tractor with spray tanks, AC 4-row no-till planter with broadcast spray attachments, disk, 4-bottom plow, field cultivator, and 4-row Lilliston rolling cultivator. Other equipment needed, such as a stalk chopper chisel plow, etc. will be borrowed from cooperating farmers. Seed, fertilizer, and chemicals needed are purchased by the SWCD for leased acreage but are provided by cooperating farmers for demonstration plots.

Not all tillage treatments could be accomplished as planned for this first year in the replicated trials. Plowing and chiseling, intended for fall practices, were done in the spring, since land and equipment were not available in the fall. Crop residue from 1975 was the same for all tillage at a particular site; thus, residue effect on tillage cannot be measured. In two of the trials (Shanebrook and Stieglitz), row direction must be opposite from the 1975 rows in order to have plots go across existing tile lines. This would be too non-uniform for no-till planting, so these plots were disked once this year.

Corn and soybean plantings were begun on April 23 and May 21, respectively, on the well drained Whitaker soil. The only major problem at planting was in getting coulter penetration and seed cover in no-till planting on the poorly structured Nappanee silt loam soil. Corn germination was variable in these plots.

Weeds not controlled with no-plow systems were primarily species resistant to herbicides used. These included field bindweed, morning glory, and Canadian thistle. The pre-emergence herbicides used were an Aatrex-Bladex-Lasso-Paraquat combination on corn and a Lorox-Lasso-Paraquat combination on soybeans.

Another interesting observation during the growing season was the development of phytophthora root rot disease of soybeans in the Nappanee silt loam trial. It became much more severe in no-till and disk plots than in deep tilled plots, and yields were reduced by 75%.

All three of the conservation tillage demonstrations appear to be successful. The sod-planted corn showed no drouth stress during an early season dry period, while other corn in the same field was showing drouth symptoms. Moisture conserved with no-till sod planting is a prime advantage for this system on well drained soils.

Grain yields are being checked for both corn and soybeans in replicated and demonstration trials. While tillage practices in this first year of the revised study do not always represent intended tillage systems (for reasons previously stated), information gained on chisel and disk tillage should be of great interest to farmers in the watershed.

Promotion of Conservation Tillage

Farmers in the watershed have been made aware of the tillage trials underway through field tours and mass-media coverage. A field tour of the trials on July 13 drew 60 area farmers. Ft. Wayne television Farm Director Wayne Rothgeb filmed segments at planting and at several times later during the growing season. Newspaper coverage has also been very good. Conservation advantages of the no-plow tillage systems and soils where they are likely to be adapted were emphasized in all contacts with farmers.

CROP SEQUENCE AND FALL TILLAGE EFFECTS ON SOIL EROSION

by

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The Black Creek Watershed, a 4,850 ha sub-watershed of the Maumee River Basin is an area of intensive farming with an estimated 60% of the area devoted to row crop (corn and soybean) culture. The dominant cultural practices used in corn and soybean production within the watershed consists of fall turn plowing, secondary tillage for seedbed preparation in the spring and cultivation for weed control. Although this method of crop production is agronomically sound (except on highly erosive soils), it does leave a large percent of the watershed unprotected and subject to erosion during a large part of the year. Conservation tillage systems have been shown to effectively reduce soil erosion at several locations in the Cornbelt where erosion is a problem (1, 2, 6, 7). It is important, then, to determine the effectiveness of these conservation tillage systems in reducing the soil erosion and resultant sedimentation problems in the Black Creek Watershed.

There is also increasing concern that soil erosion from soybeans is much more serious than from corn. Workers in Iowa (5) showed corn following soybeans to be 40% more erosive than either soybeans following corn or continuous corn using conventional tillage. Indiana workers (3) showed that with a common-prior-crop history there was no significant difference in soil erosion from soybeans or corn from planting until harvest. This would indicate that the residual effects of the prior crop may have more influence on soil erosion than the present crop.

Since the corn-soybean rotation is a very common rotation in the Black Creek Watershed and since there is some indication that there is an interaction effect of tillage system and crop sequence on soil erosion, it was felt desirable to measure these effects within the Watershed.

Specific objectives of this study are, therefore, to:

1) determine the effects of tillage system and crop sequence on crop residue cover.

2) determine the effects of tillage system and crop sequence on soil erosion.

3) evaluate the relation between crop residue cover and soil erosion.

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PROCEDURE

Tillage Treatments

Test sites were prepared after harvest in the fall on areas that had been previously cropped to either corn or soybeans. A description of the test locations is found in Table 1. Crop rows of the prior crop were approximately up and down slope at all four locations. Prior crop residues were not removed prior to applying the tillage treatments. The tillage treatments applied in the fall were:

1) Check - No tillage performed after harvest of crops. All residues left on the surface.

2) Disk - Light disking (5-7 cm deep) - slight incorporation of residues.

3) Chisel - Chiseling (15-20 cm deep) - some incorporation of residues.

4) Plow - Plow (15-20 cm deep) - nearly all residues buried.

No further tillage treatment was applied prior to applying simulated rain tests in the late spring. Weeds were controlled in late spring by spraying plots with a contact herbicide. At the time of the simulated rain tests the plots had undergone the winter weathering process and were representative of the erosion potential that would likely occur in late winter and early spring. This would correspond to Wischmeier's (8) Fallow Period for the three tillage treatments and Crop Residue Period (Crop stage period 4) for the Check treatment.

All tillage treatments were replicated once. Individual plots were 1.8 m by 10.7 m. A paired plot-randomized block design was used.

Table 1. Identification of Test Locations

Location	Soil type	% Slope[1/]	Dates of Tests[2/] corn	soybeans
1. Yerks Farm	Haskins loam	1.8	1974	1975
2. Hirsch Farm	Nappanee clay loam	0.7-1.0	1974	1975
3. Hirsch Farm	Hoytville silty clay	0.8	1974	1975
4. Bennett Farm	Morley clay loam	4.0-4.1	1976	1974

[1/] Plot locations were moved slightly each year to avoid confounding effects of prior year tests. This resulted in slight changes in % slope at some of the locations.

[2/] Designates prior crop as well as the year the simulated rainfall tests were made. All tests were conducted between May 15 and June 15.

Surface Residue Measurement

Six photographs (slides) of the surface of each of the tillage plots were taken immediately prior to applying the simulated rainstorms. The slides were then projected on a grid and estimates were made of the amount of surface covered by crop residues. The results from the 6 photos were averaged and reported as % surface cover.

Simulated Rainfall Tests

Simulated rainfall tests were conducted during May-June and consisted of the following:

Initial storm - 60 minutes of rainfall at 6.35 cm/hr.

Wet storm - 30 minutes of rainfall at 6.35 cm/hr applied twenty-four hours following the initial storm.

Very wet storm - 30 minutes of rainfall at 6.35 cm/hr applied fifteen minutes after the end of the wet storm.

Samples were taken from the 0-15 and 15-30 cm depth for antecedent soil moisture determinations prior to the initial and wet tests. Runoff rates and amounts were determined by the use of flumes and water stage recorders and 1% aliquot samples of runoff were taken throughout the test for determining sediment load and composition. Procedures developed in earlier studies (4) for conducting simulated rain tests and analyzing the results were used in this study.

RESULTS AND DISCUSSION

Surface Cover

The effects of prior crops (soybeans and corn) and tillage system on percent surface residue cover are presented in Table 2. These results show that various forms of fall tillage do have a significant influence on the amount of residues remaining on the surface the following spring. Obviously, the treatment that did no incorporation (check) had the highest amount of surface cover after both corn and soybeans. The disk treatment reduced soybean residues, but had little if any influence on corn residues when compared to the check. Generally, residues remaining after chiseling were appreciably lower than the check on both corn and soybeans. Plowing resulted in the least residues, as was expected, however, the differences between plowing and other treatments were much less following soybeans than corn. In fact, the difference in surface residues between chisel and plow treatments following soybeans were minor and probably did not significantly influence runoff and erosion.

The results show a major difference in the amount of surface cover remaining in the spring following corn as compared to soybeans. Although the plow system which essentially buried all of the residue, whether corn or soybeans, resulted in little if any difference in cover, all three of the other treatments in most cases showed corn to have significantly more residues remaining than soybeans.

Table 2. Crop and Tillage Effect on % Surface Cover [1/]

Soil	Tillage	% Cover	
		Soybeans	Corn
HASKINS LOAM			
	Check	21	57
	Disk	8	55
	Chisel	--	36
	Plow	4	1
NAPPANEE CLAY LOAM			
	Check	15	53
	Disk	9	58
	Chisel	10	29
	Plow	3	5
HOYTVILLE SILTY CLAY			
	Check	24	78
	Disk	12	77
	Chisel	9	57
	Plow	1	4
MORLEY CLAY LOAM			
	Check	26	69
	Dick	17	70
	Chisel	12	25
	Plow	1	7

[1/] Surface cover determined photographically. Each value listed is an average of 6 determinations.

In another study (3) where surface cover was measured immediately after harvest in 102 cm-width rows, surface cover was actually greater following soybeans than corn (95% vs 60%). This resulted from the better distribution of soybean residues from the "combine" harvestor than from corn where the picker-sheller left corn stalks well in tact.

The major decrease of the surface soybean residue cover as compared to the remaining corn residue the following spring which is reported in this study, probably resulted from appreciably less residue produced from soybeans than corn as well as the more rapid oxidation of the bean residues because of a lower carbon-nitrogen ratio.

Runoff and Soil Loss

Infiltration, runoff and soil loss results from the initial, wet, very wet, and 3-storm totals are given in Tables 3-10.

Haskins Loam: The effects of tillage system following corn and soybeans on runoff and soil loss on the Haskins loam are presented in Tables 3 and 4. Generally the check and disk treatments following corn results in slight increases in infiltration, therefore reduced runoff compared to the chisel and plow treatments. However, the major soil loss reductions resulting from these treatments resulted from a much lower sediment concentration of runoff as a result of the increased surface cover (See Table 2).

Table 3. Summary of Results by Test Storms, May-June, 1974, Haskins Loam

		1973[1/] Crop-Corn			Slope 1.76% slope
Treatment	Storm	Appl. (cm)	Infil. (cm)	Runoff (cm)[1/]	Soil Loss t/ha [2/]
Check	Initial (60 min)	6.35	3.86	2.49	3.20
Disk	"	6.35	3.10	3.25	2.44
Chisel	"	6.35	3.10	3.25	5.78
Plow	"	6.35	1.96	4.39	12.25
Check	Wet (30 min)	3.17	1.70	1.47	.94
Disk	"	3.17	1.17	2.00	.72
Chisel	"	3.17	.71	2.46	4.01
Plow	"	3.17	.63	2.54	6.81
Check	Very Wet (30 min)	3.17	1.09	2.08	1.12
Disk	"	3.17	.36	2.82	.76
Chisel	"	3.17	.38	2.79	3.99
Plow	"	3.17	.41	2.76	7.01
Check	Total (2 hours)	12.70	6.65	6.05	5.26
Disk	"	12.70	4.62	8.08	3.92
Chisel	"	12.70	4.19	8.51	13.78
Plow	"	12.70	3.00	9.70	26.07

[1/] Results are averages of two replications. To convert cm to in, divide by 2.54. To convert t/ha to T/A divide by 2.24.

[2/] Runoff and soil loss have been adjusted to a constant intensity of 6.35 cm/hr.

Both reduced runoff and sediment concentration of the runoff were responsible for less soil loss from the chisel treatment than the plow treatment. Greater surface roughness (more surface storage) and surface cover contributed to effectiveness of the chisel system.

The effect of tillage system in reducing soil loss following soybeans (Table 4) shows the check treatment to be far more effective than either the disk or plow treatment. This reduction results from lower sediment concentration rather than reduced runoff. For some unknown reason, the soil loss from the disk treatment is extremely high based on the amount of surface cover present. The chisel treatment was not applied in the fall so a spring plow treatment was included in its place. The spring plow treatment proved to be effective in reducing the runoff because of greatly increased plow-layer storage. It has long been known that recently plowed land is highly receptive to large amounts of water infiltration and storage.

Table 4. Summary of results [1] by test storms, May-June-1975. Haskins loam - 1974 crop soybeans - slope 1.80%.

Treatment	Storm	Appl. (cm)	Infil. (cm)	Runoff[2] (cm)	Soil Loss[2] (t/ha)
Check	Initial (60 min)	6.35	1.93	4.42	3.54
Disk	"	6.35	1.35	5.00	9.92
Sp. Plow	"	6.35	5.13	1.22	1.39
F. Plow	"	6.35	1.70	4.65	9.54
Check	Wet (30 min)	3.17	.66	2.51	1.72
Disk	"	3.17	.58	2.59	3.99
Sp. Plow	"	3.17	1.32	1.85	2.22
F. Plow	"	3.17	.69	2.49	4.19
Check	Very Wet (30 min)	3.17	.48	2.69	1.75
Disk	"	3.17	.66	2.51	3.45
Sp. Plow	"	3.17	.97	2.21	2.69
F. Plow	"	3.17	.89	2.29	3.88
Check	Total (2 hrs.)	12.70	3.07	9.63	7.01
Disk	"	12.70	2.59	10.11	17.36
Sp. Plow	"	12.70	7.42	5.28	6.29
F. Plow	"	12.70	3.28	9.42	17.61

[1] Results are averages of two replications. To convert cm to in, divide by 2.54. To convert t/ha to T/A, divide by 2.24.

[2] Runoff and soil loss have been adjusted to a constant intensity of 6.35 cm/hr.

A comparison of the interaction effect of crop sequence and tillage on surface cover and resulting erosion is shown for the Haskins loam in Table 11. The results show that the interaction effect is great for both the check and disk treatments in that surface cover from soybeans is only 37% and 15%, respectively, of that from corn. This further implies that the fall disking increases the decomposition rate of soybean residue, but has little influence on breakdown rate of corn residue. Little importance is attributed to the greater cover from soybeans than corn on the plowed treatment since both had less than 5% surface cover (Table 2).

Soil loss ratios of soybeans/corn show soil losses to have a strong inverse relationship to amounts of surface cover. Although the soil erosion from the check treatment on the soybeans is abnormally low the 4^+ fold increase in soil loss from disked soybeans supports this observation.

Nappanee Clay Loam: The effects of tillage following corn and soybeans on runoff and soil loss are shown in Tables 5 and 6. Treatments had little consistent influence on water infiltration, thus runoff, following corn (Table 5). The major soil loss reductions shown for the check, disk and chisel treatment, therefore, were the result of reduced sediment concentrations of the runoff. Although soil losses from the chisel treatment were much greater than from the check and disk treatments, they were appreciably lower than that from the plow treatment. The soil loss differences again appeared to be closely related to surface cover.

Table 5. Summary of Results by Test Storms, May-June, 1974, Nappanee Clay Loam.

		1973[1/] Crop Corn		Slope 0.66%	
Treatment	Storm	Appl. (cm)	Infil. (cm)	Runoff[2/] (cm)	Soil Loss[2/] (t/ha)
Check	Initial (60 min)	6.35	3.20	3.15	.90
Disk	"	6.35	3.35	3.00	.72
Chisel	"	6.35	3.38	2.97	2.22
Plow	"	6.35	3.51	2.84	4.14
Check	Wet (30 min)	3.17	1.47	1.70	.36
Disk	"	3.17	2.11	1.06	.16
Chisel	"	3.17	1.37	1.80	1.08
Plow	"	3.17	1.47	1.70	1.72
Check	Very Wet (30 min)	3.17	1.12	2.05	.38
Disk	"	3.17	1.32	1.85	.20
Chisel	"	3.17	.79	2.38	1.41
Plow	"	3.17	.79	2.38	2.15
Check	Total (2 hours)	12.70	5.79	6.91	1.64
Disk	"	12.70	6.78	5.92	1.08
Chisel	"	12.70	5.54	6.16	4.71
Plow	"	12.70	5.77	6.93	8.01

Table 6 shows that tillage effects on runoff following soybeans were minor compared to the effects following corn. There appears to be slightly less soil loss from the check and disk treatments than from the chisel and plow treatments. Surface cover (Table 2) was low for all treatments and explains to a great extent, the absence of major tillage effects on soil loss.

Table 6. Summary of results[1] by test storms, May-June 1975. Nappanee clay loam-1974 crop - Soybeans - Slope 1.03%.

Treatment	Storm	Appl.[2] (cm)	Infil. (cm)	Runoff[2] (cm)	Soil Loss[2] (t/ha)
Check	Initial (60 min)	6.35	2.77	3.58	5.20
Disk	"	6.35	1.70	4.65	7.68
Chisel	"	6.35	2.44	3.91	8.54
Plow	"	6.35	2.36	3.99	7.01
Check	Wet (30 min)	3.17	.81	2.36	3.22
Disk	"	3.17	.76	2.41	2.71
Chisel	"	3.17	.86	2.31	3.79
Plow	"	3.17	.89	2.29	3.58
Check	Very Wet (30 min)	3.17	.71	2.46	3.16
Disk	"	3.17	.89	2.29	2.76
Chisel	"	3.17	.81	2.36	4.37
Plow	"	3.17	.53	2.64	3.58
Check	Total (2 hrs)	12.70	4.29	8.41	11.36
Disk	"	12.70	3.35	9.35	12.63
Chisel	"	12.70	4.11	8.59	15.84
Plow	"	12.70	3.78	8.92	14.18

[1] Results are averages of two replications. To convert cm to in, divide by 2.54. To convert t/ha to T/A, divide by 2.24.

[2] Runoff and soil loss have been adjusted to a constant intensity of 6.35 cm/hr.

Ratios of soybeans/corn (Table 11) further illustrate the interaction effect of crop sequence and tillage system on both surface cover and soil loss. Soybeans were only 28, 16, and 24% as effective as corn in developing surface cover on the check, disk, and chisel treatments, respectively. Again, values for the plow treatment have little significance since percent cover following both corn and soybeans was less than 6%. These results agree with those on the Haskins soil in that fall disking reduced soybean residue cover, but had little, if any, effect on corn residue.

Soil losses from the check, disk and chisel system following soybeans were several times the losses following corn. These differences can largely be explained by the differences in residue cover. The less dramatic increase of soil loss from soybeans versus corn on the plowed treatments must have resulted from the residual effect of plowing under greater amounts of residue following corn than beans, since surface cover was not a factor here.

Hoytville Silty Clay: Tillage effects on runoff and soil loss following corn and soybeans are given in Tables 7 and 8. Tillage treatments had little consistent effect on runoff after corn except for the chisel where runoff was greatly reduced (Table 7). There was little difference in soil loss from the check and disk treatments, but both were extremely effective compared to the plow treatment. Surface cover effect on sediment concentration again appeared to be the major factor in soil loss reductions (Table 2). In the case of the chisel treatments, the reduced soil loss was primarily a result of less runoff, however reduced sediment concentration was also a factor.

Table 7. Summary of Results[1] by Test Storms, May-June, 1974, Hoytville Silty Clay

Treatment	Storm	1973 Crop-Corn		Slope 0.75%	
		Appl (cm)	Infil. (cm)	Runoff[2] (cm)	Loss[2] (t/ha)
Check	Initial (60 min)	6.35	3.38	2.97	.54
Disk	"	6.35	4.42	1.93	.38
Chisel	"	6.35	5.11	1.24	.60
Plow	"	6.35	3.35	3.00	2.02
Check	Wet (30 min)	3.17	1.73	1.44	.25
Disk	"	3.17	2.08	1.09	.31
Chisel	"	3.17	2.54	.63	.27
Plow	"	3.17	1.22	1.95	1.08
Check	Very Wet (30 min)	3.17	1.02	2.15	.31
Disk	"	3.17	.79	2.38	.25
Chisel	"	3.17	1.37	1.80	.78
Plow	"	3.17	.94	2.23	1.21
Check	Total (2 hours)	12.70	6.12	6.58	1.10
Disk	"	12.70	7.29	5.41	.94
Chisel	"	12.70	9.02	3.68	1.66
Plow	"	12.70	5.51	7.19	4.30

[1] Results are averages of two replications. To convert cm to in, divide by 2.54. To convert t/ha to T/A, divide by 2.24.

[2] Runoff and soil loss have been adjusted to a constant intensity of 6.35 cm/hr.

Tillage effects following soybeans (Table 8) were highly variable. As can be seen in Table 2 surface cover was relatively low on all treatments and apparently had only minor effects on sediment concentrations of the runoff. The plow treatment, probably because of topographical variations, appears to be the most effective in reducing soil loss. The results do indicate that where residue cover is limited that fall tillage effects on runoff and soil loss in the spring are minor.

Table 8. Summary of results[1] by test storms, May-June, 1975. Hoytville Silty Clay - 1974 crop-Soybeans-Slope 0.77%.

Treatment	Storm	Appl. (cm)	Infil. (cm)	Runoff[2] (cm)	Soil Loss[2] (t/ha)
Check	Initial (60 min)	6.35	2.54	3.81	4.19
Disk	"	6.35	1.14	5.21	3.96
Chisel	"	6.35	2.16	4.19	5.29
Plow	"	6.35	3.00	3.35	2.69
Check	Wet (30 min)	3.17	1.12	2.05	1.66
Disk	"	3.17	.97	2.20	1.30
Chisel	"	3.17	.94	2.23	2.73
Plow	"	3.17	1.75	1.42	1.21
Check	Very Wet (30 min)	3.17	1.02	2.15	1.95
Disk	"	3.17	.69	2.48	1.59
Chisel	"	3.17	1.42	1.75	1.30
Plow	"	3.17	.64	2.53	1.37
Check	Total (2 hrs)	12.70	4.67	8.03	7.80
Disk	"	12.70	2.79	9.91	6.85
Chisel	"	12.70	4.52	8.18	9.32
Plow	"	12.70	5.38	7.32	5.26

[1] Results are averages of two replications. To convert cm to in, divide by 2.54. to convert t/ha to T/A, divide by 2.24.

[2] Runoff and soil loss have been adjusted to a constant intensity of 6.35 cm/hr.

The ratios of soybeans/corn comparing both surface cover and soil loss on the Hoytville silty clay agree fairly closely with the results from the other locating (Table 11). Surface cover is greatly reduced across all tillage systems following soybeans as compared to corn. Partial incorporation of soybean residues hastened their decomposition while tillage treatments following corn were much less affected. On all but the plow treatment, soil loss from soybean land was several fold that from corn land. The almost complete inversion of the residues by plowing evidently eliminated most of the interaction effect between tillage system and crop sequence on soil erosion.

Morley Clay Loam: Tables 9 and 10 show the tillage effects on runoff and soil loss. Tillage treatments on corn land had little consistent effect on runoff (Table 9). The only treatment where runoff amounts were appreciably different was the chisel treatment where increased amounts were observed. This result is not in agreement with those from other studies where chiseled cornland usually reduces runoff. Soil losses on this sloping soil were shown to be greatly reduced by both the check and disk treatments. These effects can be largely attributed to effective surface cover (Table 2). Soil loss reduction attributed to the chisel treatment was much less, probably as a result of only 25% of the surface covered at the time of the test storm. Reduced sediment concentration of runoff was the factor responsible for reduced soil loss.

Table 9. Summary of tillage results[1] by test storms May-June, 1976. Morley Clay Loam - 1975 crop - corn. Slope 4.14%.

Treatment	Storm	Appl. (cm)	Infil. (cm)	Runoff[2] (cm)	Soil Loss[2] (t/ha)
Check	Initial (60 min)	6.35	1.83	4.52	1.32
Disk	"	6.35	1.65	4.70	1.39
Chisel	"	6.35	1.27	5.08	8.31
Plow	"	6.35	3.15	3.20	9.88
Check	Wet (30 min)	3.17	1.12	2.05	.52
Disk	"	3.17	1.02	2.15	.60
Chisel	"	3.17	.71	2.46	3.36
Plow	"	3.17	.76	2.41	5.69
Check	Very Wet (30 min)	3.17	.99	2.18	.54
Disk	"	3.17	1.04	2.13	.52
Chisel	"	3.17	.43	2.74	3.34
Plow	"	3.17	.56	2.61	6.27
Check	Total (2 hrs.)	12.70	3.94	8.76	2.38
Disk	"	12.70	3.71	8.99	2.51
Chisel	"	12.70	2.41	10.29	15.01
Plow	"	12.70	4.47	8.23	21.84

[1] Results are averages of two replications. To convert cm to in, divide by 2.54. To convert t/ha to T/A, divide by 2.24.

[2] Runoff and soil loss have been adjusted to a constant intensity of 6.35 cm/hr.

Table 10 shows tillage treatment on soybean land to have significant effects on soil loss on the Morley clay loam. The results are in agreement with other locations in that tillage treatment had little effect on runoff, but is not in agreement with the results at the other sites regarding treatment effect on soil loss. Surface cover (Table 2) was slightly higher for the check, disk, and chisel treatments at the Morley location than at the other three locations and may be partially responsible for greater soil loss reductions. Sediment concentrations in the runoff were about 30% of those of the plow treatment for both the check and disk treatments while the concentrations of the chisel treatment were about 70% those of the plow.

Table 10. Summary of Results[1] by Test Storms, May-June, 1974, Morley Clay Loam

		1973 Crop-Soybeans		Slope 3.99%	
Treatment	Storm	Appl. (cm)	Infil. (cm)	Runoff[1] (cm)	Soil Loss[1] (t/ha)
Check	Initial (60 min)	6.35	1.45	4.90	5.94
Disk	"	6.35	1.91	4.44	6.63
Chisel	"	6.35	1.91	4.44	14.86
Plow	"	6.35	1.50	4.85	21.97
Check	Wet (30 min)	3.17	.53	2.64	3.36
Disk	"	3.17	.86	2.31	2.84
Chisel	"	3.17	.69	2.48	7.93
Plow	"	3.17	.51	2.66	10.30
Check	Very Wet (30 min)	3.17	.10	3.07	4.08
Disk	"	3.17	.41	2.76	2.96
Chisel	"	3.17	.41	2.77	2.96
Plow	"	3.17	.64	2.53	8.62
Check	Total (2 hours)	12.70	2.08	10.62	13.37
Disk	"	12.70	3.18	9.52	12.43
Chisel	"	12.70	3.00	9.70	30.26
Plow	"	12.70	2.65	10.06	40.90

[1] Results are averages of two replications. To convert cm to in, divide by 2.54. To convert t/ha to T/A, divide by 2.24.

[2] Runoff and soil loss have been adjusted to a constant intensity of 6.35 cm/hr.

Table 11 again shows strong interaction effects between crop sequence and tillage system on surface cover and soil loss. Cover from soybeans was only 38, 24, 48 and 14 percent as great as from corn on the check, disk, chisel, and plow treatments, respectively. The significance of the ratio for the plow treatment is questionable because of the low residue cover values.

These resultant cover differences following tillage after soybeans versus corn are responsible for several fold differences in soil losses between the two crops. These findings further strengthen the need to consider the interaction effects of tillage system and crop sequence before assigning soil reduction credit for a particular tillage system.

Table 11. A comparison of surface cover and soil loss between soybeans and corn.

Soil	Tillage	Surface Cover soybeans/corn	Soil Loss soybeans/corn
HASKINS LOAM	Check	.37	1.3
	Disk	.15	4.4
	Chisel[1/]	---	---
	Plow	4.00	0.7
NAPPANEE CLAY LOAM	Check	.28	7.0
	Disk	.16	11.7
	Chisel	.34	3.4
	Plow	.60	1.8
HOYTVILLE SILTY CLAY	Check	.31	7.1
	Disk	.16	7.3
	Chisel	.16	5.6
	Plow	.25	1.2
MORLEY CLAY LOAM	Check	.38	5.6
	Disk	.16	7.3
	Chisel	.48	2.0
	Plow	.14	1.9

[1/] Spring plowing substituted for fall chisel so no comparison is possible.

CONCLUSIONS

These results are still considered to be of a preliminary nature and further analyses might alter them slightly. However, several conclusions can be made at this time. These include:

a) Tillage systems performed in the fall have significant effects on the amount of crop residue remaining on the surface in the spring. Surface cover averaged over four locations amounted to 21, 11, 10, and 2% respectively, for the check, disk, chisel and plow treatments following soybeans. Following corn these values were 64, 65, 37, and 4%.

b) There is a strong interaction between crop sequence and tillage system as to their effect on surface cover. When averaged over the four locations, surface residue cover in the spring after fall tillage following soybeans was 33, 18, and 33% respectively, of that after corn from the check, disk and chisel treatments.

c) Soil losses in the spring are much greater following a crop of soybeans than following a crop of corn. Averaged over four locations, land following soybeans was found to be 5.2, 7.1, 2.7 and

1.4 times more erosive than land following corn from the check, disk, chisel and plow treatments, respectively. This relationship did not appear to be greatly different on the nearly level lake plain soils or the sloping glacial till soils. It should be mentioned, however, that soil losses across all treatments were much lower on the nearly level sites than on the sloping sites. Another point should be made about these data. They represent only the most erosive part of the fallow and crop residue periods, not the entire season.

d) Soil losses are inversely related to percent surface cover. Generally, the greater the surface cover, the less the erosion regardless of the crop involved. However, some crops produce more total residue than others and the residue produced decomposes slowly because of high carbon-nitrogen ratios. A good example is corn versus soybeans.

e) Those tillage systems that leave large amounts of crop residues on the surface are effective in significantly reducing soil erosion in the Black Creek Watershed. Particularly effective are check (no till) and disk treatments following corn since large amounts of surface residue still remain in the spring. Fall chiseling following corn although not as effective as the two treatments mentioned above, significantly reduces erosion, compared to plowing. The degree of erosion control is dependent upon the amount of surface cover remaining as well as the roughness of the surface. None of the conservation treatments are as effective following soybeans as following corn because of reduced surface cover. Chiseled soybean land can be particularly erosive following a poor crop and when chisel marks run up and down slopes.

f) Gross field erosion is 3 or more times greater from the sloping soils in the watershed than from the nearly level portions. For this reason, it is still more important to concentrate conservation tillage and other conservation practices in the more erosive areas.

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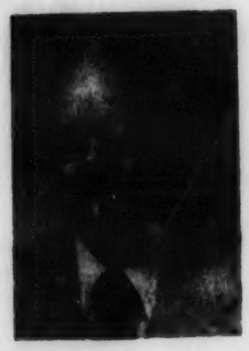

SEDIMENT YIELD FROM AN AGRICULTURAL WATERSHED INTO THE MAUMEE RIVER

by

E. J. Monke*

ABSTRACT

The annual sediment yield from the Maumee River into Lake Erie averages around 500 kg/ha from the entire Maumee Basin. This sediment, consisting almost entirely of suspended load, may be contributing to the eutrophication process in Lake Erie by acting as the transporting agent for chemicals notably phosphorus.

During 1975, the sediment production from the Black Creek Watershed into the Maumee River averaged about 3900 kg/ha. This rate was substantially higher than the estimated 1000 kg/ha for 1974 and was caused by greater than average rainfall. Also several large storms occurred during May when around 50 percent of the land surface had been just recently tilled. Total phosphorus and nitrogen runoff were 9 and 78 kg/ha, respectively.

Two subwatersheds were studied in particular: One contained 26 percent mostly level and 74-percent rolling topography and was 40-percent in row crops, and the other contained 71-percent mostly level and 29-percent rolling topography and was 63-percent in row crops. The first subwatershed had a sediment yield of 5400 kg/ha as compared to 3500 kg/ha for the latter. Phosphorus yields were about the same for both watersheds even though the sediment yields were substantially different. Higher fertility levels were maintained in the more level subwatershed, however. The nitrogen yield was 67 kg/ha for the first subwatershed as compared to 89 kg/ha for the other. Again the more level subwatershed had higher fertilizer application rates. It is also extensively tile drained. The difference in sediment yield from the two subwatersheds suggests that the more rolling land contributed a large share of the total yield even though the soil surface was better protected (40 vs 63-percent in row crops). The major portion of the soil loss from the more level lands occurred only during the large storm events.

The best management practices for reducing soil erosion in the watershed seem to be those practices which protect the most soil surface over the longest period of time. Any form of minimized tillage and better residue management would fall into this category. A best management practice for substantially reducing the off-site effects of erosion is the temporary storage of runoff. Parallel, tile-outlet terraces (also reduces field soil loss) and small detention reservoirs located near the outlets of tributary drains are examples where the temporary slow-down and storage of runoff waters may allow 90-percent or more of the sediments to drop out.

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INTRODUCTION

The Maumee River is usually a gently flowing river and even in flood periods the velocities are relatively low because the gradient is not steep. However, the waters in the Maumee River never appear clear because of its suspended sediment load. For a 10-year period of record, 1961-71, the sediment rate from the Maumee River into Lake Erie averaged about 500 kg/ha annually (1,2). However, sediment yields even of this rather low order of magnitude may be highly active because they are composed mostly of colloidal-sized particles. For a small volume, the sediments can and do carry a large loading of chemicals notably phosphorus. Unknown at this time, however, is the contribution of the phosphorus which is attached to sediments to the eutrophication rate of Lake Erie. That some of the attached phosphorus becomes available to the degradation process is implicitly assumed in this study.

The relatively low annual sediment yield into Lake Erie probably is not very detrimental to the agricultural productivity of the Maumee Basin. Also this low rate consisting mainly of colloidal-sized particles suggests that control may be difficult. Soil conservation practices are more effective with larger-sized particles which tend to readily fall out when runoff velocities are reduced.

Wolman (3) estimates that duration of sediment transport may take around 20 years in the major river systems of the United States. Certainly the sediment output of the Maumee River is an imprecise indicator, then, of the causative factors of sedimentation. Also we do not know the state of equilibrium of the Maumee River bed -- whether it is aggrading, degrading or at steady state. However, we are currently facing a major problem of the degradation of water quality in Lake Erie. Non-point source pollution from watershed areas must be measured and means of control studied and implemented even though we may have to estimate the ultimate off-site benefits. One such source area currently being studied is the Black Creek Watershed.

BLACK CREEK WATERSHED

The Black Creek Watershed was chosen as being fairly representative of the soils and agricultural practices of the Maumee Basin although it is only 4900 ha in size compared to 1,711,500 ha for the Maumee Basin. An outline map of experimental watershed is shown on Figure 1.

The soils in the Black Creek Watershed can be roughly divided into two categories -- those soils which were formed entirely in glacial till and those soils which were also influencied at various stages in their formation by shallow water cover or by wave action. These soil categories are subsequently referred to as glacial till soils and lake plain and beach soils, respectively. Indiana Highway 37 as shown in Figure 1 divides these soils fairly well with the glacial till soils to the north and the lake plain and beach soils to the south. The glacial till soils also are gently rolling while the lake plain soils in particular are nearly level.

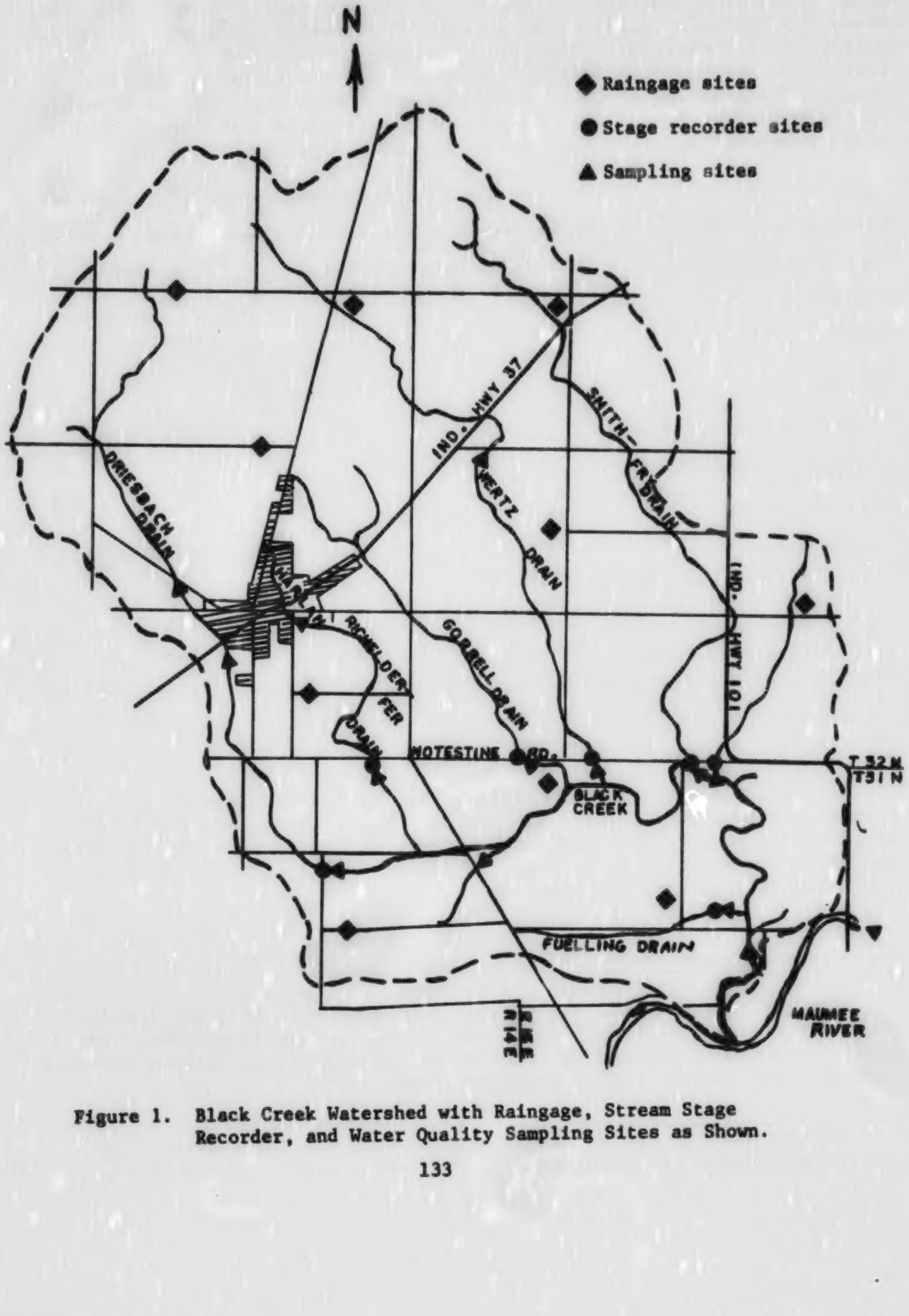
N
◆ Raingage sites
● Stage recorder sites
▲ Sampling sites
DRIESBACH DRAIN
HARLAN
IND. HWY 37
SMITH-FRY DRAIN
WERTZ DRAIN
GORRELL DRAIN
RICHELDERFER DRAIN
NOTESTINE RD.
BLACK CREEK
IND. HWY 101
T 32 N
T 31 N
FUELLING DRAIN
MAUMEE RIVER
R 15 E
R 14 E

Figure 1. Black Creek Watershed with Raingage, Stream Stage Recorder, and Water Quality Sampling Sites as Shown.

Five major drains empty into the main stem of Black Creek. Two of these drains were studied in particular -- the Driesbach Drain which is located along the western boundary of Black Creek Watershed and the Smith-Fry Drain which is located along the eastern boundary of the watershed. These two drains, of comparable size, represent the greatest contrast in soils and land use to be had in the watershed. The Driesbach Drain contains 74-percent rolling and 26-percent nearly level topography while the Smith-Fry Drain contains only 29-percent rolling and 71-percent nearly level topography. Also, in 1975, the Driesbach Drain was 40-percent in row crops while the Smith-Fry Drain was 63-percent in row crops. The drainage areas of the Black Creek Watershed and the Driesbach and Smith-Fry Drains as well as percentages of these areas in the major soil categories and 1975 land use practices are given in Table 1.

Table 1. Characteristics of the Black Creek Watershed and the Driesbach and Smith-Fry Drains

Characteristics	Black Creek Watershed	Driesbach Drain	Smith-Fry Drain
Drainage area	4950 ha	735 ha	890 ha
Soils:			
Lakes plain and beach	64%	26%	71%
Glacial till	36%	74%	29%
1975 land use:			
Row crops	58%	40%	63%
Small grain and pasture	31%	44%	26%
Woods	6%	4%	8%
Urban, roads, etc.	5%	12%	3%

SEDIMENT YIELDS

Sediment yields as well as chemical runoff (4) from the major tributary drains into Black Creek and from Black Creek into the Maumee River are being determined by integrating concentrations with flow rates. The primary water quality sampling sites, stream stage recorder sites and raingage locations are shown in Figure 1.

Evaluating Sediment Yield

Stage-discharge relationships have been developed for the principal tributary drains which enter into Black Creek to give flow rates. Water levels are being continuously recorded at these locations with a pressure-type recorder (Model 12 Flow Recorder, Foxboro)*.

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*The product description and manufacturer are given for reader information and should not be contrued as an endorsement of the product.

Water samples for determining the concentration of sediment as well as other quality parameters are being collected either manually or with automated samplers. Grab samples are routinely collected each week and then at select times usually following a storm event. The automated samplers are triggered at a set minimal stage and continue to operate automatically until the sampling capacity is exhausted. Usually, however, the water samples are collected and the automated sampler reset before this happens.

Three automated pumping samplers (PS-69, developed by the U.S. Interagency Sedimentation Project) were installed at the junction of the Driesbach and Smith-Fry Drains with Black Creek and on the main stem of Black Creek near its entrance into the Maumee River. Each sampler is capable of automatically collecting 72 samples on a set time interval. At the present time, a 500 ml water sample is collected every 30 min after the sampling sequence has been initiated. Samples are being collected from the suspended sediment profile of the streams near the elevations at which the automated samplers are triggered.

Sediment and Nitrient Yields for 1975

The automated pumping samplers became operational early enough in 1975 to sample most of the major storm events occurring during the year. The most extreme event during 1975 occurred in May when about 90 mm of rainfall fell over the entire watershed in 2 hours. Rainfall frequencies were estimated from 50 to 100 years at the various raingage locations (5).

The 1975 values of average depth of rainfall and runoff over the drainage areas and the suspended sediment, total nitrogen and total phosphorus yields on a unit area basis are given in Table 2.

Table 2. Rainfall, Runoff, and Sediment, Nitrogen and Phosphorus Yields from the Black Creek Watershed and the Driesbach and Smith-Fry Drains for 1975

Parameter	Black Creek Watershed	Driesbach Drain	Smith-Fry Drain
Rainfall	1130 mm	1130 mm	1120 mm
Runoff	490 mm	480 mm	490 mm
Sediment	3900 kg/ha	5400 kg/ha	3500 kg/ha
Nitrogen	78 kg/ha	67 kg/ha	89 kg/ha
Phosphorus	9 kg/ha	9 kg/ha	8 kg/ha

During 1975, about 1130 mm of rainfall occurred over the Black Creek Watershed. This was 26-percent above the average rainfall at Ft. Wayne. Of this amount, 490 mm or more than one-third of the annual rainfall was discharged from Black Creek into the Maumee River. Sediment, nitrogen and phosphorus yields on a unit area basis were 3900 kg/ha, 78 kg/ha and 9 kg/ha, respectively. The sediment yield was substantially higher than the estimated 1000 kg/ha which occurred during 1974. However, only about 760 mm of rainfall occurred during 1974 which was 16-percent below the average rainfall for this locality.

Nearly one-third of the total sediment yield for the year occurred during May mostly from several intense storms which took place during the latter part of the month when nearly 50-percent of the land had been just recently tilled. One storm in particular caused scouring on the nearly level lake plain soils which are usually not affected much by less severe storms. Existing drains were overtopped, temporary new drainageways established, and sufficient runoff velocities occurred to cause quite severe erosion on that portion of the watershed containing these soils. Also a great share of the recent tillage had been accomplished in this part of the watershed.

Samples from 20 tile drain outlets were collected weekly. Based on the analysis of the outflow from these drains, the contribution of subsurface drainage systems to the total sediment yield from the watershed was estimated at 200 kg/ha. The contribution from tile drains represents about 5-percent of the total sediment yield into the Maumee River.

Comparison Between Two Subwatersheds

Rainfall and runoff depths for the Driesbach and Smith-Fry Drains were approximately the same. However, the sediment yield for the Driesbach Drain was approximately 50-percent higher than the Smith-Fry Drain even though 63-percent of the area contributing runoff to the Smith-Fry Drain was in row crop agriculture compared to 40-percent for the Driesbach Drain. The difference in sediment yield from the two subwatersheds suggests that the more rolling land consisting mostly of the glacial till soils contributed a large portion of the sediment yield from the Black Creek Watershed into the Maumee River. Based solely on the areas occupied by the principal soils, the sediment yield from the glacial till soils would be around 6500 kg/ha as compared to 2400 kg/ha for the lake plain and beach soils.

Total phosphorus yields were about the same from both subwatersheds even though the sediment rates were substantially different. The total nitrogen yield for the Driesbach Drain was 67 kg/ha as compared to 89 kg/ha for the Smith-Fry Drain. Higher fertility levels were maintained on the land contributing runoff to the Smith-Fry Drain, however.

The subwatershed contributing runoff to the Driesbach Drain contain portions of the rural community of Harlen. A substantial portion of the nitrogen and phosphorus loadings undoubtedly came from this community due to direct waste discharge into the Driesbach Drain. This would tend to further separate the unit area contributions of phosphorus and particularly nitrogen from the agricultural lands of the two subwatersheds.

CONTRIBUTING FACTORS TO SOIL EROSION

For 1975, the primary contributing factor to erosion in the Black Creek Watershed was the large amount of bare soil surfaces which were exposed to intense storms during late May and early June. Over one-half of the watershed area is normally in rowcrop agriculture. During this time of the year, nearly all of this land had either been recently worked or planted to crops. Nearly one-half of the total sediment yield occurred during this period. During one severe storm, the outlet drains overtopped onto the nearly level lake plain soils causing severe erosion. Ordinarily very little surface erosion would be expected from these lands which cover approximately the lower one-half of the watershed.

The average annual streambank erosion from the Black Creek Watershed has been estimated at 9 kg/ha (6). Although this erosion rate is small, eroded soils are directly available for transport in the streams. More streambank erosion undoubtedly occurred during 1975 because of the severe storms and recent construction on some of the outlet drains. However, even if increased, streambank erosion would probably only represent a small percentage of the total sediment yield to the Maumee River.

Tile drainage effluent also contributed to the sediment yield from the Black Creek Watershed. Tile effluent was sampled weekly from about 20 select tile outfalls. However, none of the first flush occurring after a storm or thaw was sampled and no samples were collected when the tile outlets were inundated. Based on the samples from the 20 tile outfalls, the sediment yield from the tile drains in the watershed was estimated at 100 kg/ha. However, this value should probably be doubled to account for the peak yields which were missed. The sediments which are discharged from the tile drains, however, are colloidal-sized particles. Also, these sediments are discharged directly into the stream system of the watershed where they are directly available for transport to the Maumee River.

The tile drains in the watershed have been observed to sometimes flush large quantities of drainage water into streams during the winter and early spring months. This occurrence is primarily dependent on temperature although rainfall which probably occurs at the same time may increase the discharge. When the soil surface freezes, a surface seal is formed which transfers free soil water above the tile drains into a negative pressure state. Tile discharge for all practical purposes stops although downward movement of water in the soil may still take place. Then when thawing occurs, the drains seem to flush. High seepage pressures may also simultaneously occur causing movement of sediments into the drain. Many freeze-thaw cycles often occur at this latitude during the winter-early spring months of the year.

BEST MANAGEMENT PRACTICES

The best management practices for reducing soil erosion in Black Creek Watershed seem to be those practices which protect the most soil surface over the longest period of time. Any form of conservation tillage and better residue management could fall into this category (7). Prior to 1975, many of the obvious localized sources of erosion such as sluffing of some ditch banks and gully erosion at the upper ends of the drains had been remedied. However, during 1975, severe erosion from land surfaces, even from the nearly level surfaces of the lake plain soils, occurred. Surface erosion from the nearly level topography was caused by intense storms, one with a return period of 75 years, which took place during the planting season. Measures to protect the nearly level lands may not be cost effective, however, because even with the intense storms which occurred during 1975, the erosion rate from the nearly level lands was estimated to be only about one-third of the rate on the gently rolling glacial till soils located in the upper portion of the watershed.

This difference in erosion rates between the nearly level lake plain soils and the gently rolling glacial till soils occurred even though the soils in the glacial till area seemingly were better protected. Around 46-percent of the area containing the glacial till soils was in rowcrop agriculture while 63-percent of the area containing the lake plain and beach soils was in rowcrop agriculture. Conservation tillage and better residue management would be very beneficial on the more rolling lands of the watershed in particular.

A best management practice for substantially reducing the off-site effects of erosion is the temporary storage of runoff. Recently installed parallel, tile-outlet terraces and one small detention reservoir are allowing 90-percent or more of the sediments to drop out (8,9,10). The terrace systems are also good erosion control structures because they decrease the volume and velocity of surface runoff by reducing the slope length. The small detention reservoir is located near the outlet of a tributary drain into Black Creek. The uniform depth of sediments over its entire area suggests that it is an effective trap even of the smaller-sized sediments. The location of the reservoir does not help to reduce sediments getting to it, however.

Relating Sediment Yield to Best Management Practices

Sediment yield from the Black Creek Watershed can only be related to best management practices in general terms with the one possible exception of the small detention reservoir where 90-percent or more of the sediment coming from the land is trapped. It is difficult to quantify sediment yield reductions for specific practices because these practices may cover a small portion of the area above a gaging and sampling station and because the effectiveness of a practice varies with time and management. Then, also, the period of record has so far been short. As an aid for quantifying sediment yield reductions for specific practices, a distributed watershed model is being developed (11,12). This model will have the ability to further define what is now known only in a general way.

SUMMARY

For 1975, the sediment yield from the Black Creek Watershed into the Maumee River was 3900 kg/ha. Major storm events during late May and early June caused about one-half of the total sediment load. Since many drains were overtopped from one particularly intense storm, severe scouring on the nearly level portions of the watershed contributed a normally disproportionate share of the total sediment yield. Even so, the sediment yield from the nearly level portion of the watershed was estimated at only 2400 kg/ha as compared to 6500 kg/ha from the gently rolling portion. Best management practices put into the upper one-third of the watershed on the gently rolling glacial till soils should prove to be the most beneficial of any location in the Black Creek Watershed.

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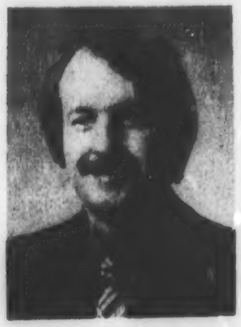

NUTRIENT CONTRIBUTIONS TO THE MAUMEE RIVER

by

D. W. Nelson, L. E. Sommers, and A. D. Bottcher[*]

ABSTRACT

Total amounts of water, sediment, and nutrients discharged from two subwatersheds of the Black Creek study area during 1975 were determined. In excess of 5000 kg of sediment/ha was transported past the two sampling sites during the year. Quantities of most nutrient forms were similar to those observed in other watershed studies except that the amounts of nitrate N discharged were high (25-34 kg/ha). Most of the total P transported was sediment-bound P, whereas a substantial proportion of the total N in stream water was nitrate. Partitioning the total amounts of sediment and nutrients transported by type of flow indicated that small hydrological events were responsible for most transport, however, large events transported a higher proportion of sediment and sediment nutrients in relation to water discharge as compared to other types of flow. Amounts of suspended and soluble constituents transported in base flow was low. Surface runoff was the major source of sediment, sediment-bound nutrients, ammonium N, and soluble organic N and P transported in the subwatersheds. Significant proportions of nitrate N originated in tile drainage and subsurface drainage water. A substantial proportion of soluble inorganic P was derived from septic tank effluent in one subwatershed containing a large number of houses. Calculation of proportions of N and P added as fertilizer and manure which were recovered as soluble inorganic nutrients in streams indicate that significant losses of added N are occurring in the watershed. Very low losses of added P were observed.

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INTRODUCTION

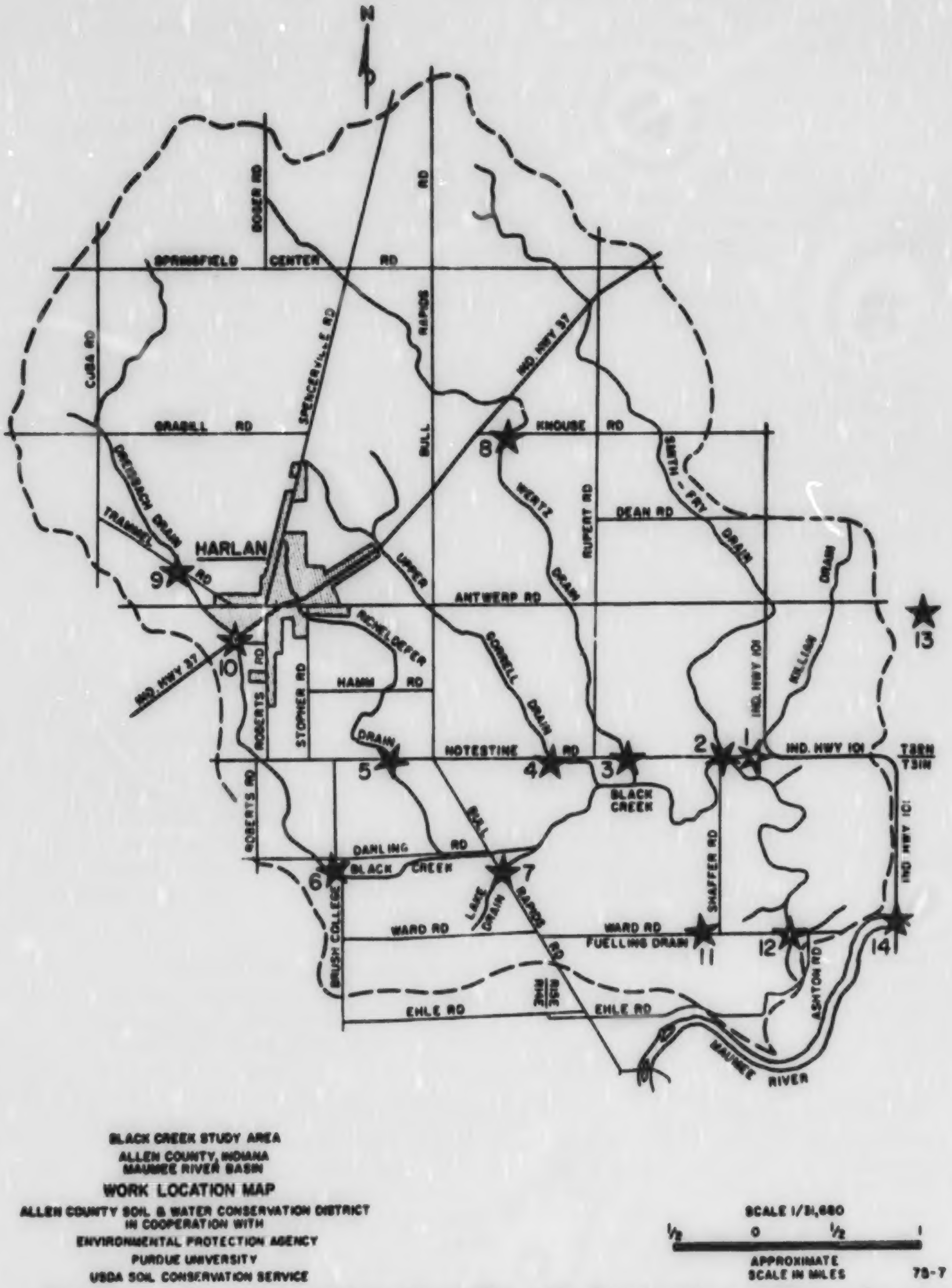
The primary objectives of the Black Creek study are to determine: (1) the sources and amounts of sediments and nutrients being transported from agricultural land to surface water resources, and (2) the effects of applying soil conservation practices to the land on the amounts of sediment and nutrients that are being contributed to streams and lakes by water runoff and subsurface flow. Therefore, two of the major tasks involved in the Black Creek study are to determine the amounts of nutrients and sediments that are flowing in the drainage ditches in the watershed throughout the entire period of the year and to analyze transport associated with specific storm events to determine the periods of year when most of the nutrients and sediments are delivered to surface waters.

During 1975, we were able to accurately measure the amounts of water flowing past sampling sites 2 and 6 in the Black Creek watershed and were able to adequately sample the water for quality parameters throughout the course of the year. By using computer techniques we were able to calculate the fluxes of sediments and nutrients transported within the watershed. For the first time in Black Creek study, data is available which allows estimates of the contributions of various land use activities to water quality in the watershed. We were also able to determine the types of storms which transport most of the sediments and nutrients and were able to determine the relative contributions of rainfall, soil runoff, subsurface flow, and human population activities to sediment and nutrient concentrations in the streams. This paper is a discussion of our findings concerning sediment and nutrient transport in the Black Creek watershed during 1975. Similar data will soon be available for 1976. However, the 1976 data has not been completely collected or analyzed.

MATERIALS AND METHODS

Figure 1 presents a map of the sampling locations within the Black Creek watershed. This report will deal with detailed flow measurements and sampling conducted at sites 2 and 6 in the watershed. Site 2 receives drainage water from largely level, heavily-cropped, and relatively heavy-textured soils. Little drainage water derived from upland soils passed by site 2. Site 6, on the other hand, receives a substantial amount of drainage water from a rather rolling upland area containing a significant proportion of Amish farms. Site 6 also receives drainage water and sewage wastes from the town of Harlan. Consequently, at site 6 a lesser proportion of total drainage water is received from level, heavy-textured soils which are intensely farmed. These two sampling sites provide a contrast in land use patterns and in size of human population discharging waste into agricultural drainage ditches.

Table 1 presents detailed information on the characteristics of the subwatersheds which contribute runoff and subsurface flow to sites 2 and 6. Site 2 receives drainage from an area of 942 hectares of which approximately 421 hectares are tile drained. There are 28 houses in the drainage area which contribute water to site 2. Site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WERTZ DRAIN
RUPERT RD
DEAN RD
DRAIN
KILLIAN
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TRAMMEL RD
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ANTWERP RD
RICHELDEFER
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CORNELL DRAIN
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T32N
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BLACK CREEK
ROBERTS RD
BULL
SHAFFER RD
DARLING RD
6
BLACK CREEK
7
LAKE DRAIN
RAPIDS RD
IND HWY 101
BRUSH COLLEGE
WARD RD
WARD RD
FUELLING DRAIN
11
12
ASHTON RD
14
R13E
R14E
EHLE RD
EHLE RD
MAUMEE RIVER
BLACK CREEK STUDY AREA
ALLEN COUNTY, INDIANA
MAUMEE RIVER BASIN
WORK LOCATION MAP
ALLEN COUNTY SOIL & WATER CONSERVATION DISTRICT
IN COOPERATION WITH
ENVIRONMENTAL PROTECTION AGENCY
PURDUE UNIVERSITY
USDA SOIL CONSERVATION SERVICE
SCALE 1/31,680
1/2
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APPROXIMATE
SCALE IN MILES
73-7

Figure 1 Location of Sampling Sites for Evaluation of Water Quality

6, on the other hand, drains an area of 714 hectares of which about 431 hectares are served by tile systems. There are approximately 143 houses in the subwatershed drained by the ditch flowing past site 6. It is also of interest to note that 705 water samples were taken at site 2 during 1975, whereas 441 water samples were taken at site 6. It is felt that this number of samples adequately characterized the water flowing past the two sites during 1975. Values in Table 1 for amounts of tile drainage water and subsurface drainage water which are flowing into ditches in the watershed are estimates based upon other studies conducted in similar soils and upon the hydrology of the Black Creek watershed.

Table 1. Characteristics of the subwatersheds studied

	Site 2	Site 6
Area, ha	942	714
Tiled area, ha	421	431
Rainfall, cm	107	107
Combined runoff & subsurface drain	53.7	48.5
Tile drainage, cm	12.7	12.7
Subsurface drainage tiled areas, cm	15.4	12.7
Subsurface drainage untiled areas, cm	22.9	22.9
Houses in watershed	28	143
Estimated N applied, Kg	40246	33080
Estimated P applied, kg	31934	24205
Water samples taken	705	441

Flow past sites 2 and 6 was continuously monitored by a weir stage recorder system and flow rate was calculated by solution of the flow equation which involves the cross-sectional area of the weir, the flow velocity of the stream, and the stage of the stream. Flow velocities were estimated by measurements made in the watershed and by the grade of the stream. Total flow for 1975 was derived by integrating the flow curve for the entire year. Water samples were taken on a weekly basis by use of a grab sample technique. Additional water samples were taken during storm events by use of an automatic water sampler (PS-69). Water samples were immediately frozen and transported to the laboratory where they were analyzed for total solids, total P, total N, ammonium N, nitrate N, soluble organic N (SON), soluble inorganic P (SIP), soluble organic P (SOP), and soluble organic C. Concentrations of solids and nutrients were multiplied by the flow over the period of time which the sample represented yielding values for sediment and nutrient transport. The resultant values were summed to arrive at the total amounts of solids and of the various forms of nutrients which flowed past the two sampling sites for the entire year.

In partitioning of the data into type of flow events, base flow was taken as anytime when the stage was less than 12.5 cm and large storms were defined as storms that produced more than 2.5 cm of runoff. Small storms are thus defined as any runoff event yielding a stage greater than 2.5 cm with the stipulation that the storm produce less than 12.5 cm of runoff. Amounts of nutrients present in precipitation were calculated by multiplying the average concentration of nutrients in precipitation samples times the total amount of precipitation which fell upon the landscape during 1975. The amounts of nutrients transported in subsurface drainage water flowing into ditches were estimated by multiplying the concentration of nutrients in subsurface flow (assumed to be the same as those in tile drainage water) by the estimated amount of water flowing into the ditches from subsurface flow. The amounts of nutrients present in tile drainage water were similarly estimated by multiplying the average concentration of nutrients present in the tile drainage water measured in that subwatershed times the estimated flow of water from the tile drains in the watershed.

RESULTS AND DISCUSSION

Total Amounts of Sediments and Nutrients Transported During 1975:

Table 2 gives data on total amounts of nutrients and sediment transported past sites 2 and 6 during 1975. The amounts of sediments were fairly consistent between the two sites; however, higher amounts of soluble nutrients were present in water flowing past site 6 as compared to site 2. The amounts of sediment-bound nutrients at site 2 were higher than those at site 6. It is interesting to note that the amounts of SIP, SOP, and ammonium N are substantially higher (when expressed on a kilogram per hectare basis) in water flowing past site 6 as compared to that flowing past site 2. This finding is to be expected if septic tanks effluent is contributing substantial amounts of soluble nutrients to the drainage ditches in the site 6 subwatershed due to the larger number of houses present in this subwatershed. Furthermore, it is interesting to note that the amount of nitrate N flowing past site 2 is considerably higher than that flowing past site 6 even though the amount of tile drained land in these two subwatersheds is approximately the same. The higher nitrate content in water flowing past site 2 may result from the fact that cropland in the site 2 watershed receives higher amounts of nitrogeneous fertilizers than do soils in the other subwatershed. It is also interesting that even though the total amounts of sediment passing sites 2 and 6 is approximately equal, the amounts of sediment N and P in water flowing past site 2 is markedly higher than that in water passing site 6. This finding indicates that sediment passing site 2 contains considerably higher amounts of P and N constituents than sediment passing site 6 and may reflect the relative nitrogen and phosphorus status of the soils in the two subwatersheds. When taken as a whole, the sediment and nutrient losses in the two subwatersheds were generally similar to those of other agricultural watersheds previously studied, with the exception that nitrate N losses in the Black Creek watershed were generally quite large (from 25 to 33 kilograms of N per hectare).

Table 2. Amounts of nutrients and sediment transported past sites 2 and 6 during 1975.

Component	Site 2	Site 6
Water, cm	53.8	48.5
Sediment, Kg/ha	5644	5402
Soluble inorganic P, kg/ha	0.331	0.581
Soluble organic P, kg/ha	0.175	0.231
Sediment P, kg/ha	11.526	7.357
Ammonium N, kg/ha	2.75	3.39
Nitrate N, kg/ha	33.65	25.14
Soluble organic N, kg/ha	3.38	3.90
Sediment N, kg/ha	71.84	34.73

Table 3 presents data on the forms of phosphorus present in water flowing past sites 2 and 6. At site 2, sediment P made up almost 96% of the total P transported during the year, whereas at site 6 sediment P represented 90% of the total P transported. At site 6, SIP accounted for 7% and SOP represented approximately 3% of the total P transported in 1975. These values for site 6 are higher than the percentages of total P which were represented by SIP and SOP in water flowing past site 2, and likely reflect the contribution of septic tank effluent to the total flow in the subwatershed which discharges into the ditch flowing past site 6.

Table 3. Proportion of total P transported as soluble inorganic P, soluble organic P, and sediment-bound P past sites 2 and 6 during 1975.

	Form of P transported		
Site	Sol inorg P	Sol org P	Sed P
2	2.7	1.4	95.9
6	7.1	2.8	90.1

Table 4 presents the proportions of total N flowing past sites 2 and 6 which are present as ammonium N, nitrate N, SON, and sediment N. Sediment N accounts for 64% and 52% of the total N flowing past sites 2 and 6, respectively. Ammonium N and SON account for a relatively small proportion of the total N passing site 2, however, these forms of N account for greater than 10% of the total N passing site 6. This finding suggests that septic tank effluent may be responsible for increasing the relative proportion of soluble nutrients present in the water passing site 6.

Table 4. Proportion of total N transported in various forms past site 2 and 6 during 1975.

Site	NH_4^+-N	NO_3^--N	Sol Org N	Sed N
	% of total N transported			
2	2.5	30.1	3.0	64.6
6	5.0	37.4	5.8	51.7

It is interesting to note that nitrate N accounted for 30 to 37% of the total N passing sites 2 and 6 in 1975. This finding would indicate that it is very difficult to model N transport in an agricultural watershed when using sediment transport as the basic model because the amounts of nitrate being moved are not related to sediment or sediment nitrogen transport, but rather reflect the amounts of nitrate N present in subsurface drainage water and tile drainage water. On the contrary, it is realistic to attempt to model total P transport in a watershed based upon the sediment concentration in drainage water because total P transport and sediment transport are very closely related.

Nutrient transport as related to types of flow.

Computer techniques were used to partition the total transport of sediment and nutrients in the watershed into classes based on types of flow. Base flow was arbitrarily defined as any flow in which the stage was less than 12.5 cm and large events were defined as storms producing 2.5 cm or greater of combined surface runoff and subsurface drainage water. Small events thus comprised all flows other than base flow or large storm events.

Table 5 presents data concerning the partitioning the amounts of sediment and nutrient flowing past site 2 into three types of flow. Similar results were obtained for data collected at site 6. Although base flow occurred for 275 days during 1975, the amounts of water, sediment and nutrients transported in the site 2 subwatershed by base flow was a relatively small proportion of the total amounts of these materials transported during the year(from 2.3 to 8.9%)of the materials transported in this watershed). The largest proportion of materials which were transported past site 2 during 1975 resulted from small runoff events. From 67 to 84% of the total amounts of water, sediment, and nutrients which flowed past site 2 were transported in 30 small events which occurred during 1975. The two large runoff events which occurred during 1975 accounted for approximately 14% of the total water which flowed past site 2. However, these two storm events were responsible for transport of approximately 26% of the total sediment and sediment nutrients which were present in water flowing past site 2 during the year. Large storm events accounted for relatively low proportions (11-14%) of soluble nutrients transported in the site 2 subwatershed during the year. These findings suggest that small runoff events are largely responsible for sediment and nutrient transport in agricultural watersheds; however, large events can have a very significant impact upon the total transport of sediment and sediment nutrients because of the high soil erosion potential of heavy rainstorms associated with these events.

Table 5. Partitioning of sediment and nutrients transported past site 2 into types of flow.

Component	Base flow	Small events	Large events
	---------------- % of total transport		----------
Water	8.3	78.0	13.7
Sediment	2.3	72.3	25.5
Soluble inorganic P	5.5	83.2	11.3
Soluble organic P	8.0	77.3	14.7
Sediment P	1.8	71.7	26.5
Ammonium N	8.9	68.3	22.8
Nitrate N	5.9	83.8	10.3
Soluble organic N	4.7	81.4	13.9
Sediment N	4.0	67.5	28.6

Table 6 presents data on the average concentrations of sediment and nutrients in water flowing past site 2 of affected type of events occurring in the watershed. Similar values were obtained for the site 6 watershed. It is interesting to note that the concentrationof sediment in water passing site 2 increased as the amount of flow in the drainage ditches increased and that the mean sediment concentration for the year was much higher than the average sediment concentration during base flow periods. This finding would suggest that grab samples taken largely during base flow periods (as is customarily done in watershed studies) would not accurately characterize the sediment concentrations actually present in the watershed throughout the year. Sediment concentrations in large rainstorm events averaged almost 2000 mg/l and individual values as high as 5000 mg/l were obtained in samples taken at the peak of the run-off hydrograph.

Table 6. Average concentrations of sediment and nutrients in water passing site 2 as affected by type of flow.

	Type of flow			
Component	Total	Base flow	Small events	Large events
		mg/l		
Sediment	1050	284	973	1948
Sol. inorganic P	0.062	0.041	0.066	0.050
Sol. organic P	0.032	0.031	0.032	0.032
Sediment P	2.144	0.461	1.971	4.151
Ammonium N	0.51	0.55	0.45	0.85
Nitrate N	6.26	4.45	6.73	4.69
Sol organic N	0.63	0.36	0.66	0.64
Sediment N	13.36	0.63	11.57	27.84

There was little relationship between the SIP concentration in stream water and the type of flow. At site 2, the highest levels of SIP were associated with small runoff events, and SIP concentrations during periods of base flow and large events tended to be lower than those during small events. The concentration of SOP in drainage water was very constant throughout the entire year and was not related to types of flow events. The concentrations of sediment-bound P directly paralleled the sediment concentrations in stream water. Therefore, as the flow events became larger (from base flow to large events), the sediment P concentration also increased markedly. The concentration of ammonium N in stream water was not greatly effected by type of hydrologic event. However, there was a higher concentration of ammonium N during large runoff events as contrasted to base flow or small runoff events.

The concentration of nitrate N in stream water did not seem to be related to type of flow event, however, the concentrations of nitrate N in stream flow associated with small events tended to be higher than that associated with base flow or large events. The concentrations of SON in water did not seem to be related to the type of flow events occurring, however, somewhat lower concentrations of SON were observed in base flow as contrasted to storm events. The concentrations of sediment-bound N were directly related to the concentrations of sediment present in each type of flow event. Base flow contained low quantities of sediment-bound N, whereas the concentration of sediment N in flow resulting from storm events tended to increase as the severity of the storm event increased. Relatively high levels (average of 28 mg N/1) of sediment-bound N were present in stream water associated with large storm events.

Sources of Water, Sediment, and Nutrients in the Black Creek Watershed.

Table 7 provides data on the proportion of the total amounts of water, sediment, and nutrients transported past site 6 which originated with various sources of flow, identified in the watershed. The flow sources identified as significant were tile drainage water, subsurface drainage water (other than tiles) discharging into surface streams, effluent from septic tanks serving households in the subwatershed, and surface runoff water. Approximately one-half of the total water transported past site 6 originated from surface runoff and one-half was subsurface drainage water derived from tile systems and subsurface flow into the streams. Septic tanks effluent accounted for only about 1% of the total flow observed in the subwatershed.

Surface runoff accounted for almost 99% of the suspended solids produced in the site 6 watershed, whereas tile drainage contributed only about 1% of the total suspended solids measured during 1975. Approximately 40% of the total amount of SIP present in stream water originating from the site 6 subwatershed was derived from septic tank effluent. Surface runoff produced 42% of the SIP transported from the site 6 subwatershed. Subsurface drainage accounted for slightly less than 20% of the SIP present in stream water passing site 6.

Table 7. Sources of water, sediment, and nutrients transported past site 6 during 1975.

Component	Sources				
	Tiles	Subsurface	Septic tanks	Runoff	Precip.*
	% of total transported				
Water	15.9	34.7	1.1	48.3	-
Sediment	1.0	-	0.5	98.5	-
Sol inorganic P	5.3	11.9	40.4	42.4	(25.9)
Sol organic P	10.3	23.0	13.9	53.3	-
Sediment P	0.7	-	6.3	93.0	-
Ammonium N	4.9	10.9	13.1	71.0	(145.7)
Nitrate N	14.8	32.9	5.3	47.0	(25.2)
Sol organic N	9.3	20.7	-	70.0	-
Sediment N	0.8	-	2.4	96.8	-

* Values in parenthesis are percentages of soluble nutrients in stream water which could be accounted for in precipitation.

Surface runoff and septic tank effluent accounted for approximately 53% and 14%, respectively, of the SOP transported past site 6. Tile drainage water and subsurface drainage water accounted for a combined total of about 33% of the SOP measured in water draining from the subwatershed. About 93% of the sediment P present in drainage water passing site 6 was derived from surface runoff, whereas about 6% of the sediment P transported in the subwatershed originated from septic tanks. Surface runoff accounted for greater than 70% of the ammonium N present in water flowing past site 6. Septic tank effluent and subsurface drainage water were the sources of most of the remaining ammonium N observed in water flowing from the subwatershed. Surface runoff and subsurface water drainage contributed 70 and 21%, respectively, of the SON observed in water flowing past site 6. A substantial quantity (9%) of the SON transported in the subwatershed was derived from tile drainage water. Almost 97% of the sediment-bound N transported past site 6 originated from surface runoff, whereas septic tank effluent contributed 2.4% of the total sediment N measured in the subwatershed.

Almost 26% of the SIP flowing past site 6 was originally present in precipitation which fell on the land surface within the site 6 watershed. More than 145% of the total ammonium N and 25% of the nitrate N transported past site 6 was contained in precipitation falling within the subwatershed during 1975. This finding may, in part, account for the relatively large amounts of nitrate N observed in drainage water and surface runoff within the subwatershed because it is known that ammonium N is rapidly converted to nitrate N by soil bacteria and nitrate is readily transported in runoff and percolating water. This finding also indicates why knowledge of the concentrations and amounts of nutrients in precipitation is important if investigators are to properly partition the sources of nutrients in an agricultural watershed.

The annual average concentrations of sediment and nutrients in stream water passing site 6 and in tile drainage water, subsurface drainage water, septic tank effluent, surface runoff and precipitation samples taken within the site 6 subwatershed are given in Table 8. The average sediment content of stream water was greater than 1000 mg/l, whereas the sediment content of tile drainage water was only 70 mg/l. Surface runoff contained an average of almost 2300 mg/l of suspended sediment and surprisingly, the suspended solids content of septic tank effluent was approximately 470 mg/l. As expected, the SIP concentration in tile drainage water and subsurface drainage water was markedly lower than the SIP concentration of stream water. However, the concentration of SIP in precipitation samples was lower than the concentrations of SIP in subsurface drainage water or in surface runoff. This finding suggests that during water flow through soils or runoff of water from the soil surface equilibrium reactions release inorganic phosphorus from soil constituents to the water phase. These reactions lead to increased concentrations of SIP in percolating water and in surface runoff. High concentrations of SIP were observed in septic tank effluent, thus reemphasizing the importance of septic tanks as a source of SIP in this agricultural watershed. The concentration of SOP was generally low in drainage water from tiles, in subsurface recharge water, in surface runoff, and in stream samples taken at site 6. The concentration of SOP present in septic tank effluent was higher than those from other sources, however, it averaged only 0.6 mg/l. The concentration of sediment P present in water flowing in the stream was slightly greater than 1.5 mg/l, whereas the concentration of sediment P in surface runoff exceeded 2.9 mg/l. The concentration of sediment P in septic tank efflûent was quite high (8.4 mg/l). Tile drainage water contained only low concentration of sediment-bound P.

Table 8. Average concentrations of sediment and nutrients in stream water and in various flow sources present in the site 6 subwatershed.

Component	Stream flow	Flow source				
		Tiles	Subsurface	Septic	Runoff	Precip.
	mg/l					
Sediment	1115	71	-	471	2273	-
Sol inorganic P	0.120	0.041	0.041	4.230	0.105	0.014
Sol organic P	0.048	0.032	0.032	0.570	0.053	-
Sediment P	1.518	0.073	-	8.40	2.92	-
Ammonium N	0.70	0.22	0.22	7.99	1.03	0.46
Nitrate N	5.19	4.92	4.92	24.00	5.05	0.59
Sol organic N	0.80	0.48	0.48	-	1.17	-
Sediment N	7.17	0.36	-	15.31	14.36	-

The concentration of ammonium N in septic tank effluent was high (8 mg/l) whereas the concentration of ammonium N in water, stream water, tile drainage water, subsurface drainage water, and surface runoff was low (0.2-1.0 mg/l). Precipitation contained about 0.5 mg/l ammonium N (equivalent to 6 kg of NH_4^+-N/ha during 1975). The concentration of nitrate in tile drainage water and subsurface drainage water averaged about 5 mg/l. Similar concentrations were observed in surface runoff water and in stream water samples. The concentration of nitrate N in septic tank effluent was very high (24 mg/l) suggesting that some aeration of septic wastes occurred prior to discharge into streams. The concentration of nitrate in precipitation was approximately 0.6 mg/l (for 1975 rainfall contributed 7 kg of NO_3^- -N/ha). The concentration of SON in stream water, subsurface drainage water, and surface runoff was generally low (0.5-1.2 mg/l). The concentration of sediment-bound N were related to the concentration of sediment present in stream water, tile drainage water, and surface runoff. The sediment N content of surface runoff exceeded 14 mg/l, whereas stream water contained an average of 7.2 mg of sediment N/l. The concentration of sediment N in septic tank effluent was quite high (15 mg/l) even though the sediment content of septic tank effluent was not particularly high (470 mg/l). This would suggest that solids present in septic tank effluent contain high concentrations of N as well as P.

Nitrogen and Phosphorus Contents of Sediment and Soils in the Watershed.

Table 9 presents the average concentrations of total N and total P in soils in the watersheds and in sediment derived from various sources in the subwatersheds. The concentrations of total N and total P in sediment present in tile drainage water are similar to those concentrations present in the soils located in the subwatershed. This finding would suggest that soil materials being transported in percolating water and ultimately flowing out tile drains are representative of the soils drained by the tile systems, i.e., there is no selective enrichment of any soil fraction during the sediment transport process. Sediment present in water flowing in streams and in surface runoff contain much higher concentrations of total nitrogen and total phosphorus than do the soils in each watershed. This finding suggests that selective erosion is occurring during runoff events in the subwatershed with the result that sediment contains high proportions of clay and organic matter than the soils being eroded. There are significant water quality ramifications to this finding because the fine materials being transported as a result of selective erosion contain high quantities of N and P which are most susceptible for release to the water phase. The sediments associated with septic tank effluents contained very high concentrations of total N and total P. It seems likely that septic tank solids may be readily decomposed by aerobic organisms present in water upon discharge of septic tank effluent in the streams resulting in release of significant quantities of soluble N and P.

Table 9. Average concentrations of total N and total P in soils and sediment from various sources in watersheds draining into sites 2 and 6.

Sediment source	Total N		Total P	
	Site 2	Site 6	Site 2	Site 6
	----------------mg/kg of sediment----------			
Soils in the watershed	1725	1800	660	700
Sediment in stream	12730	6430	2040	1360
Tile drainage	1930	4990	700	1020
Septic tanks	29050	32470	17810	17820
Surface runoff	12780	6320	2040	1280

Table 10 presents data from an attempt to estimate the proportion of N and P added as manure and fertilizer to cropland which was recovered as soluble inorganic N and soluble inorganic P in stream water passing sites 2 and 6 during 1975. The method employed was to sum the amounts of soluble inorganic N and P present in precipitation falling on the subwatersheds and the amounts of soluble N and P discharged into streams with septic tank effluents. The resultant sum was subtracted from the total amounts of soluble inorganic N and soluble inorganic P present in water transported out of each watershed during 1975. The soluble nutrients present in stream water not accounted for in precipitation or in septic tank effluent were assumed to be derived from agricultural activities, largely from applications of inorganic fertilizer and animal waste. This is a simplistic approach fordetermining the amounts of added N and P lost in combined runoff and subsurface flow because no account is taken of N fixed by legumes, N and P mineralized from soil organic matter, or N and P present in runoff from barnlots or feedlots where animals are fed in confinement. However, this approach was necessary because no estimates were available for amounts of nutrients contributed by other sources. Calculations revealed that greater than 57 and 33% of the N added to cropland in subwatersheds draining into sites 2 and 6, respectively, was lost in runoff and subsurface flow. These values are very high and it seems likely that the calculation method overestimate the actual loss of added N by a substantial amount. However, the high calculated losses of N do serve to point out that significant amounts of added N are lost from cropland in the Black Creek watershed in surface and subsurface drainage water. This finding suggests that fertilizer management techniques can be effectively employed in this watershed to decrease the amounts of N removed in drainage water. The percentage of added P lost in runoff and subsurface flow from cropland present in site 2 and site 6 subwatersheds were 0.4 and 0.6%, respectively. This finding indicates that only limited amounts of added P are lost in water draining cropland in the Black Creek watershed and that good management techniques have apparently been employed to minimize losses of added P. The data presented here on losses of added P in surface and subsurface drainage water are similar to those observed previously in studies of runoff losses of applied P in small plot experiments where artificial rainfall was used.

Table 10. Estimates of the N and P added as manure and fertilizer which were lost in drainage water from subwatersheds 2 and 6.

	Site 2	Site 6
Sol inorg N not originating from precipitation or septic tanks(kg)	23265 (24.7)	11009(15.4)
Sol inorg P not originating from precipitation or septic tanks(kg)	136 (0.14)	139(0.19)
% of added N lost in runoff and subsurface flow	57.8	33.2
% of added P lost in runoff and subsurface flow	0.43	0.57

* Values in parenthesis are amounts of added nutrients apparently lost in drainage expressed as kg of nutrient per hectare.

CONCLUSIONS

The following conclusions may be drawn from the data presented in this discussion:

1. Sediment and nutrient losses in watershed are not large with the exception of high NO_3-N losses.
2. Greater than 90% of total P transported in watershed is sediment P; only 50-60% of total N transported is sediment N. N movement is more difficult to model than P transport.
3. Transport of sediment and nutrients in the watershed is associated with storm events; less than 10% is transported during base flow. Storms must be well monitored.
4. Sediment content and sediment nutrient concentrations increase markedly during storm events. Concentrations of soluble nutrients usually decrease during large storm events.
5. Surface runoff is the major source of sediment, sediment-bound nutrients, soluble P compounds, and ammonium. Subsurface drainage water is the major source of nitrate. In heavily populated parts of the watershed septic tanks may be a major contributor of inorganic P.
6. Approximately 45% of the N added as fertilizer and manure is recovered in drainage water from the watershed. Only 0.5% of the added P is recovered in drainage water.

SEDIMENT REDUCTION BY STREAMBANK MODIFICATION AND SEDIMENT TRAPS

by

R. Z. Wheaton and R. E. Land*

CHANNEL STABILITY STUDIES

Bank Stability Studies: were a part of the original plan of work. This work has been completed and reported in the proceedings of the November 1975 Seminar. It consisted of slope-mulch studies plus a 100 percent bank erosion survey by SCS staff as part of the IJC Maumee River study. This latter study reported bank erosion to be relatively small although at eroding locations it could be quite severe. To determine if a correlation might exist between bank cover, particularly trees vs. grass, and bank stability the reported data of the SCS study has been reviewed. While this data shows a strong correlation between soil type and bank erosion it is not possible to relate erosion and cover in the published data. An additional check is being made using the raw data, but it appears at this time that the effect of soil type may mask any effect of type of cover on bank erosion.

Considerable work has gone into the Black Creek watershed in stabilizing channel banks and slopes throughout the area. As reported at the 1975 Seminar the structural and the bank stabilizing practices have generally been very successful. However, continued observations throughout the study has suggested that in some reaches of the channel the bottoms may be continuing to degrade. Also, soil mechanics studies identified several locations where the channel bottoms were potentially unstable. This study showed that the most likely reason for instability was excess channel slope and often a less resistant soil material in the profile near the channel bottom. It is evident that if a channel bottom degrades that eventually even stable banks must become unstable.

In 1975 four sites were selected for study of the channel bottom stability. One on the Joe Graber farm was known to have lowered 30 to 60 cm (1 to 2 feet) deeper following revegetation of the banks. In this area small rock drop structures were installed in 1975 in an attempt to control the channel degradation. The 1976 results in this area show both degradation and aggradation above one of these structures, Figure 1. About 50 m (150 ft.) above the structure the channel has accumulated sediment and appears to be filling up but farther up stream there has been continued erosion since the last survey was made approximately one year ago. It cannot be determined at this time if the erosion occurred before the installation of the rock structure or if it is erosion since the installation of the control structure. These surveys will be repeated again in 1977 and possibly in succeeding years to determine whether or not the rock structures as installed are going to adequately control the erosion of the channel bottom.

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The Black Creek channel at Notestine Road was surveyed for a distance of 30 m (150 ft.) upstream and 65 m (200 ft.) downstream from the bridge. This is an area where rock was used for channel training. It is also an area that the soil mechanics studies indicated had a potentially unstable channel at flood flow. This channel was shown to be unstable because of the soil material in the channel bottom and also the slope, 0.25%. This 115 m (350 ft.) section has degraded approximately 42 cm (1.4 ft.) between May of 1974 and August of 1976, Figure 2. The channel has considerable grass and other water type vegetation in the bottom and it may possibly be stabilized at its present position. Additional surveys will be made to determine whether or not this channel has stabilized.

Another site on the Gorrell drain along Notestine Road for a distance of 165 m (500 ft.) downstream from the monitoring site shows the ditch bottom to be almost identical with the original. This section has an average slope of 0.2 m per 100 m (0.20%). This is the smallest slope of any of the four sites being studied. See Figure 3.

Wertz drain between Notestine Road and the main channel of the Black Creek a distance of approximately 305 m (1000 ft.) was a site of the bank slope-mulch studies. This channel reach has an average slope of 0.4% (0.4 meters per 100). Earlier observations had indicated that the channel bottom was eroding in several sites. The survey conducted in August of 1976 shows that with the exception of a section about 200 meters below the Notestine Road all of the channel has eroded. For the first 160 m (500 ft.) an average lowering of approximately 30 cm (1 ft.) has occurred between March of 1974 and August of 1976. The last 70 meters (200 ft.) above the main Black Creek channel has eroded approximately 45 cm (1.5 ft.). There are several areas in this section where erosion of the channel bottom has caused the toe of the banks to slip into the channel. This survey will be repeated in 1977 to determine if the erosion is continuing. See Figure 4.

These survey results plus other observations indicate that there are a number of sections throughout the Black Creek watershed where channel bottom erosion is producing unstable bank conditions. If this channel bottom erosion continues at the present rate it will be necessary to install some type of control structure in order to stabilize the total channel.

EFFECT OF SEDIMENT BASINS

The Sediment Pond: on the Virgil Hirsch farm was constructed in the fall of 1973 and filled to overflowing in November of that year. It serves a drainage area of 185 ha (460 acres). The soil types are Hoytville and Nappanee. The land slopes are generally less than one-half percent. With the water level at the crest of the mechanical spillway the water surface area of the pond is just over 2.4 ha (6 acres). The flood storage is 14,000 cu meters (11 acre ft.) with a detention time at flood design of 4-1/2 hours and an estimated flow-through time of one hour.

On May 18, 1976 with the assistance of the Soil Conservation Service state geologist cross sectional profiles were run every 30.4 meters (100 ft.). Depth of accumulated sediment was determined across each base line or station. These depths were determined by the use of a recording fathometer and by probing. Sediment deposits were examined for determination of particle size. Sediment samples for laboratory analysis were collected at a later date.

Sediment deposits were found to be very uniform in depth throughout the pond area with an average accumulation of 6 cm (0.2 ft.). Likewise particles size appeared to be very uniform, being primarily in the clay and silt fractions with possibly a small amount of fine sand.

Laboratory analysis of the samples confirmed that the sediment is a silty clay texture. The range of the sample analysis were as follows:

silt	52.1 -- 63.9%
clay	31.9 -- 42.0%
sand	4.2 -- 5.9%

From the depth of the sediment accumulation calculations indicate that in the nearly three year period since construction the sediment pond has accumulated approximately 1880 cu m (2400 cu yd.) of sediment. Assuming a dry weight of 857 kgm per cu meter (55 pounds per cubic foot) this amounts to an average of 2.8 tonnes per ha per year (1.2 tons of sediment per acre per year) for each of the three years of the nearly three year period from construction until the survey. However, this figure should not be considered anything more than the average accumulation for the years 1973-1976.

It may well be above the long time average because of two factors.

1. The area immediately to the north of the pond site was in a transition stage and was very subject to erosion until the conservation practices on it were completed in 1975, thus this area may have contributed above a normal amount of sediment in this three year period. There has also been some construction activity on the west end of the pond site.

2. In May of 1975 a nearly 100 year frequency storm was received. This storm produced the highest runoff volume and sediment consentrations yet measured at many of the stations. It produced between 1/3 and 1/2 of the 1975 annual sediment transport at some of the measuring stations.

The Desilting Basin: on the main stem of the Black Creek was constructed in September of 1974 and was first surveyed on July 30, 1975. A second survey was conducted July 7, 1976. Sediment samples have also been collected from this basin for particle size determination.

The first survey covering a period of approximately nine months showed an accumulation of 770 cubic meters (980 cubic yards) of material. The second survey shows an additional accumulation of 416 cu meters (530 cubic yards) in approximately a one year additional time. Sediment sample analysis are shown in Table I. This table shows only the percent sand by size fraction and does not include the finer silt and clay fractions. It is only at stations 460 and 461 where less than one-half of the sediment accumulated was in the sand size fraction.

Table 1. Percent Sand and Sizes in Desilting Basin Deposits at Stations Listed.

	Size Range in mm						Total %* Sand
Station	>2	2to1	1to.5	.5to.25	.25to.1	.1to.05	
457+000	26.58	11.68	17.36	27.46	6.67	1.48	91.23
458+000	7.94	5.15	11.52	46.07	16.43	2.44	89.55
459+000	.85	1.09	2.41	14.88	33.01	13.93	66.17
460+000	.38	.46	.19	1.28	17.02	21.24	40.57
461+000	0	0	.13	.88	13.59	21.08	35.68

*% sand is based on total dry oven weight of sample.

This would indicate that much of the material being trapped by this desilting basin is bed-load. To date no evidence has been seen of additional scour of the channel immediately below the desilting basin. The first 50 meters (150 ft.) of this basin is nearly full of sediment, Figure 5. There is considerable accumulation throughout the basin. If it continues to trap material at the present rate it will have to be cleaned out in a year or two to remain effective.

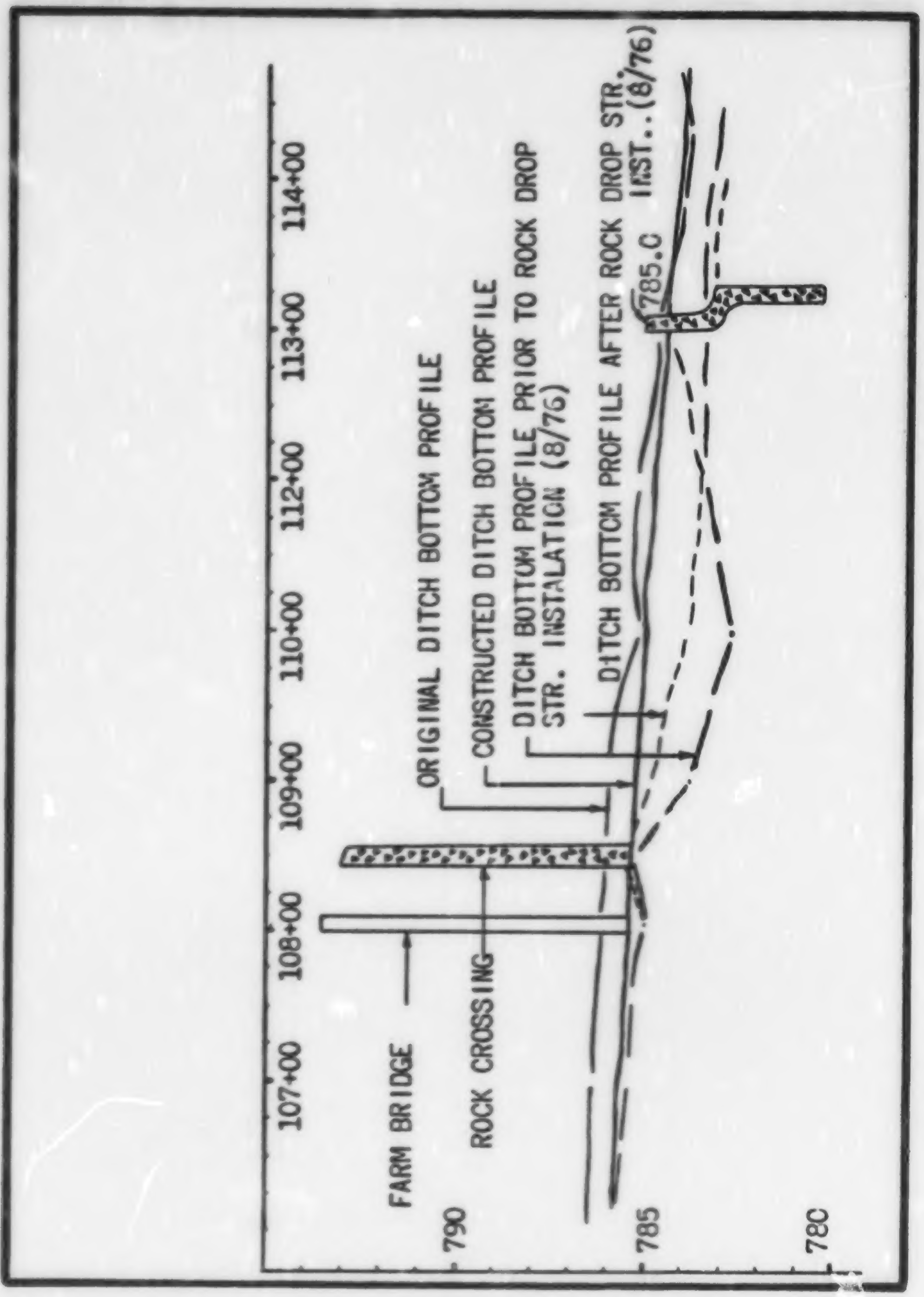
107+00
108+00
109+00
110+00
112+00
113+00
114+00
790
785
780
FARM BRIDGE
ROCK CROSSING
ORIGINAL DITCH BOTTOM PROFILE
CONSTRUCTED DITCH BOTTOM PROFILE
DITCH BOTTOM PROFILE PRIOR TO ROCK DROP STR. INSTALATION (8/76)
DITCH BOTTOM PROFILE AFTER ROCK DROP STR. INST. (8/76)
785.0

Figure 1. Profile Upper Black Creek on Graber Farm.

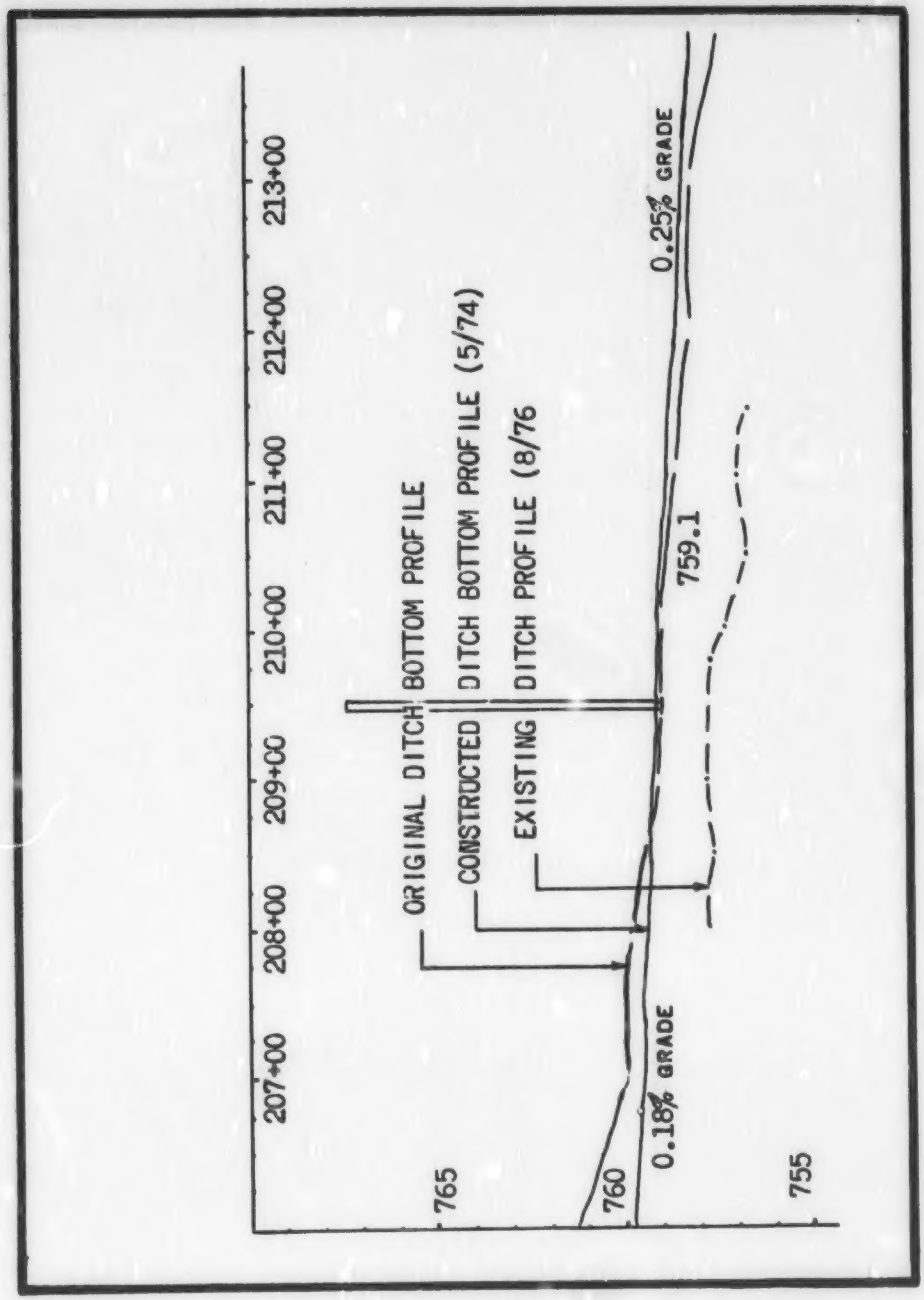

Figure 2. Profile Black Creek at Notestine Road.

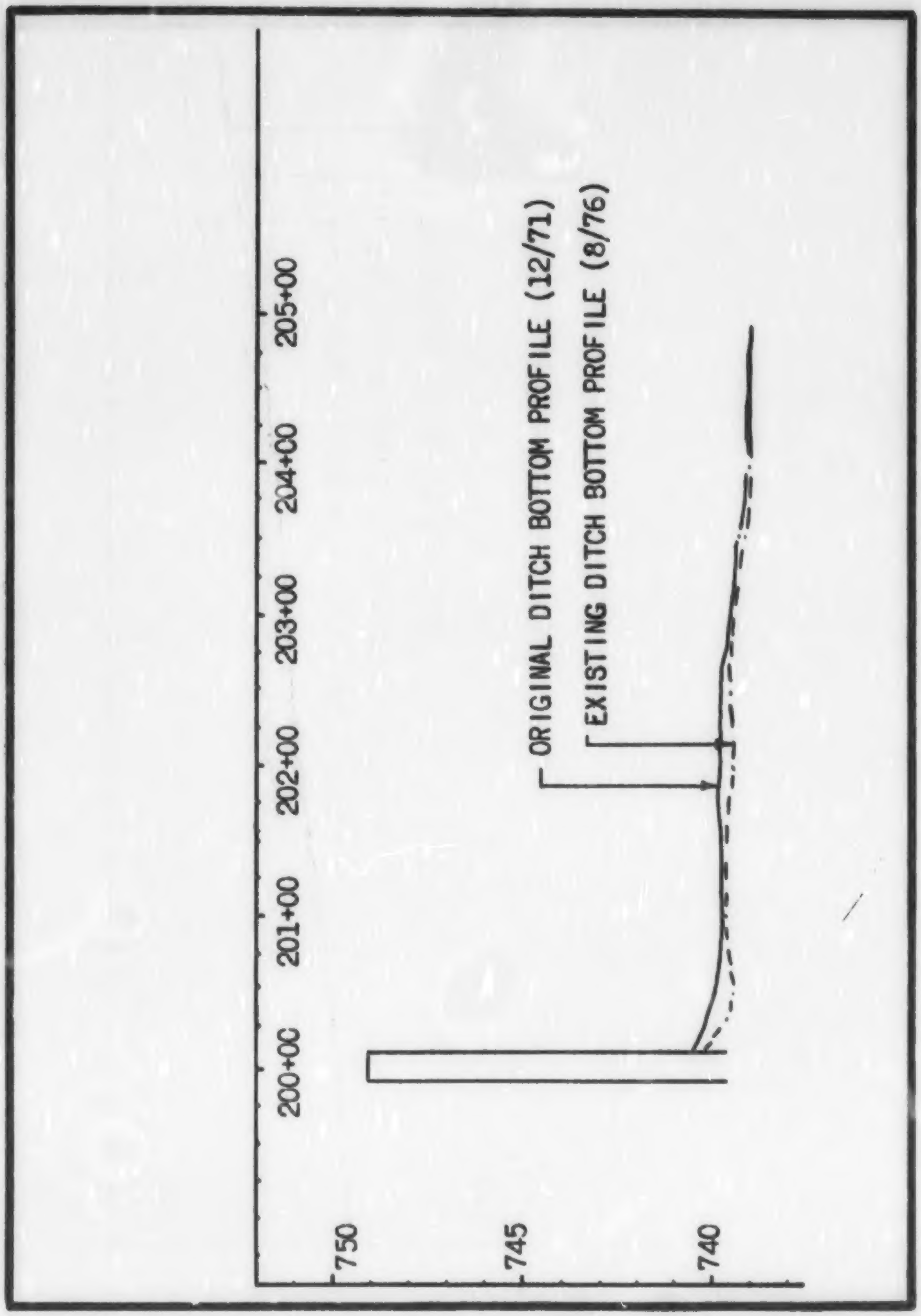

Figure 3. Profile Gorrell Drain Along Notestine Road.

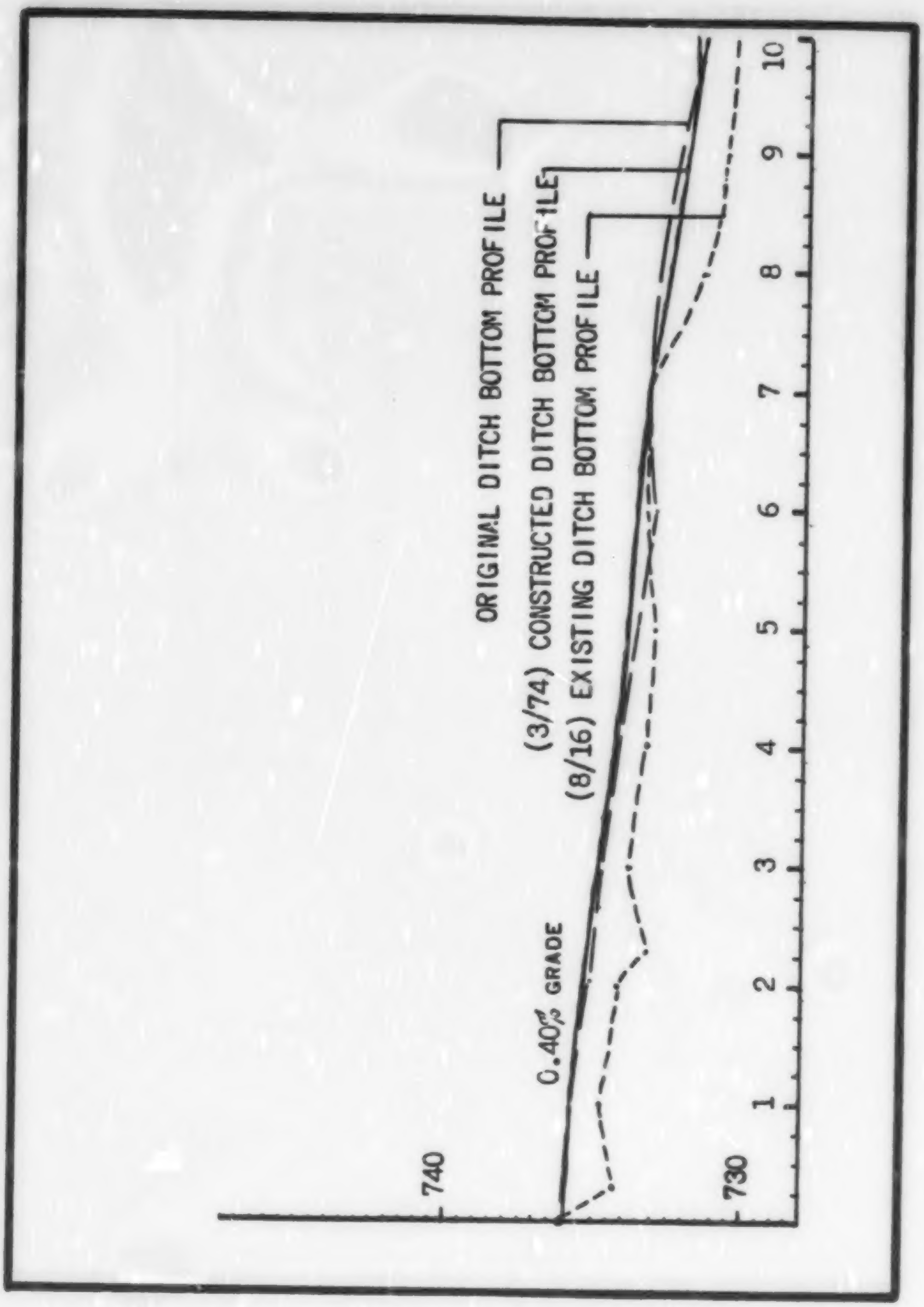

Figure 4. Profile Wertz Drain Notestine Road to Black Creek.

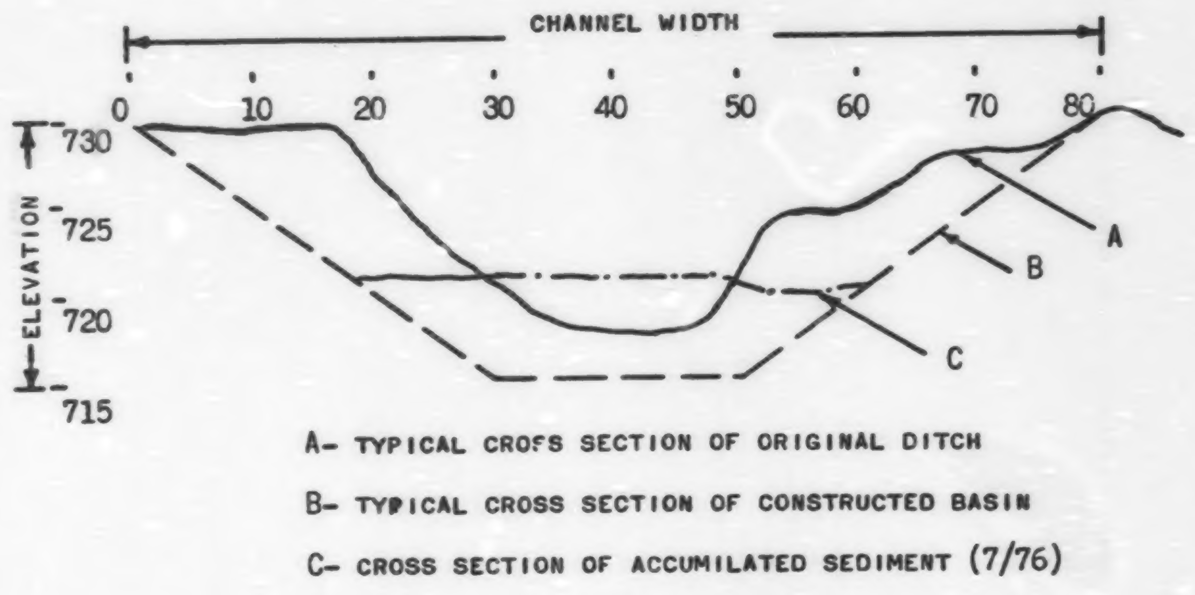

Figure 5. Typical Cross Section of Desilting Basin.

ENVIRONMENTAL DATA ACQUISITION AND REAL-TIME COMPUTERS

by

L. F. Huggins

S. J. Mahler*

One of the most important prerequisites to intelligent human decision making is the availability of complete, current and accurate information about the situation or process under consideration. This is especially true of the complex problems concerned with maintaining a suitable environment in highly industrialized societies. The nature of these problems requires an extremely wide variety of data: environmental, economic, sociological, technological and political. This paper will address the immediate and future needs related only to environmental data. Its purpose is to substantiate the hypothesis that the collection and effective utilization of large amounts of accurate environmental data is an important national need which can be dramatically and favorably influenced by employing computer assisted data acquisition techniques.

The availability of environmental data is, of course, essential to rational planning and equitable enforcement of state and federal programs concerned with improving our environment. However, these uses are by no means the only viable ones for such information. For example, Peart and Barrett (1976) have clearly outlined the food production efficiencies that may be realized by using crop ecosystem simulations as agricultural management tools. To be of value, such simulations demand extensive data concerning current and projected environmental conditions in the region of interest.

Planning is a process of evaluating the relative effectiveness and costs of alternative courses of action designed to attain stated goals. One of the evaluation methodologies which is particularly appropriate for planning non-point source pollution control programs is known as simulation. This approach utilizes a mathematical model of the system under consideration to evaluate the effectiveness of alternative control strategies. Watershed models based on the concept of using distributed parameters, Beasley (1976), appear to offer great potential toward accurately characterizing the physical aspects of non-point source pollution control measures. However, the development and verification of such models depend upon comprehensive data sets from test catchments such as the Black Creek watershed. Effective utilization of available computer technology can expand the scope of environmental parameters which may be monitored, reduce the unit cost of collecting comprehensive data sets and greatly increase the value of the data base by making it immediately available to the user.

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DATA ACQUISITION SYSTEMS

One useful method of classifying data collection systems is according to the controller to which the basic sensors are attached. This approach allows automated systems to be divided into two broad classes: data logging and real-time computer controlled. The primary emphasis of this paper concerns the latter type.

A data logging system is one in which the primary function is to record the data supplied from multiple sensors usually, on a computer readable medium, for latter analysis. Some of the more sophisticated data loggers also have options for alarm level detection and remote activation of equipment when alarm levels are exceeded. The user benefits of data logging systems are: (1) reduction of the labor and long time delay between data recording and availability of the analysis associated with strip-chart records; (2) elimination of the transcribing errors associated with converting the data into a computer compatible format prior to analysis and permanent file storage; (3) elimination of time registration errors that occur when each variable being monitored is recorded on independent clock-driven charts; and (4) expansion of the capacity for monitoring a large number of variables (channels) at small incremental cost increases, i.e. the primary expense is associated with the basic controller and recording device rather than with increasing the number of channels scanned.

A real-time computer is one which not only collects data from a process, but also has the ability to analyze that information in a time frame that is sufficiently short to effect a desired response dependent upon the results of that analysis. Thus, a real-time computer must be able to communicate at all times with sensors supplying information about the processes being monitored, i.e. in computer vernacular the transducers are referred to as being "on-line". An environmentally related example of real-time response would be monitoring rainfall distribution during storm conditions concurrently while running a watershed runoff simulation in order to be able to issue advance warnings concerning points of potential flooding hazards. In summary, the fundamental differences between data loggers and real-time systems result from the greatly expanded analytical opportunities available because the sensors are connected to an on-line computer.

Real-time Computer Functions

Real-time data acquisition inherently provides all the benefits ascribed above to data logging systems plus those resulting from the expanded analytical capabilities of an associated on-line computer. While real-time systems are generally more expensive, the additional costs are normally a small percentage of the total for an environmental data acquisition network; in view of the substantially increased benefits, they can often be easily justified.

Data acquisition: Of course, the most basic of all system functions is to acquire readings from transducers which provide outputs, normally electrical in nature, proportional to parameters being monitored. It is not the purpose of this paper to provide a detailed discussion of the transducer considerations important for configuring an environmental data acquisition system. However, the impact which an on-line computer might have on their selection is germane.

The most important factor which determines the success of a data collection system is the fidelity of the data collected. The fidelity of a data base refers to its ability to accurately portray the complete behavior of the system it purports to characterize. Data base fidelity is dependent upon: 1) proper positioning of adequate numbers of sensors to permit continuous inference of the complete state of the processes under study and 2) the operational reliability of all components of the data acquisition system. Selection of sensor location is highly process dependent and outside the scope of this paper. However, the fact that operational reliability is strongly influenced by system organization as well as tranducer hardware selection is inadequately appreciated. Assembling a system to collect data from a dispersed network of unattended instruments which must operate over wide environmental extremes is not easy; it requires both careful selection of reliable instruments as well as proper system configuration. This latter consideration involves the design of a system with redundancy and cross-checking measurements. An on-line computer contributes to both of these areas. First, it affords a direct means of providing a redundant data recording system. No real-time data acquisition which is intended to maintain a continuous historical data file should solely rely on the on-line computer to record incoming data. A backup data logging capability, preferably battery powered, which requires neither the computer nor the communication link between the computer and the field instruments should be a part of the system. Secondly, the analytical capacity of an on-line computer makes it feasible to institute quite sophisticated transducer error detection schemes. In addition to the very simple alarm limit approach, one can incorporate tests for rates of change on single and correlated variables. Cross checking can also be program controlled. For example, air temperature readings can be combined with net solar radiation data to yield independent estimates of soil temperatures adequate to detect a questionable operational status for a soil temperature transducer.

Since the communication link to an on-line computer is a two-way path, it is a comparatively minor task to implement operational control to field equipment which is dependent upon environmental conditions. Consider the data acquisition needs associated with monitoring non-point source pollution in a stream. Many of these pollutant problems are storm related and involve rapidly changing concentrations. A real-time computer monitoring hydrometerological conditions in a watershed can control the activation of remote pumping water samplers to collect frequent samples during rapidly changing conditions, but infrequent samples during slowly changing conditions. Such an approach simultaneously improves the fidelity of the data base and reduces the cost of subsequent water sample analyses.

Data Archiving/Retrieval: An integral part of any data collection program is the "permanent" storage of data in a format suitable for subsequent intended uses. This function, outlined in detail by Wong, et al (1976), is virtually unchanged between real-time and off-line systems. However, the virtually instantaneous availability of current as well as historical data files with on-line systems has many ramifications for utilizing this information.

Analysis and Interpretation: The real payoffs for real-time systems almost all are direct consequences of immediately applying the phenomenal analytical capability of a general purpose computer to data arriving from a remote sensor network. It is the elimination of the time lag between the acquisition of data and its analysis/interpretation which makes real-time systems attractive. Of course, any benefits to be realized are totally dependent upon the ingenuity of the persons responsible for developing the computer programs which must analyze all incoming data.

An example of one application for real-time analysis was alluded to above in the discussion concerning detecting erroneous data and instrument malfunctions. This application takes advantage of the efficiency with which computers perform repetitive, mundane tasks. By making a series of validity checks on each piece of received data the percentage of time instruments are operating satisfactorily can be increased while simultaneously reducing field service costs by eliminating unnecessary field inspections.

Simulation models are computer programs composed of groups of mathematical relationships which describe the behavior of physical processes occurring in the system being modelled. When real or hypothetical data concerning physical constants and boundary conditions are supplied, the resulting model predicts, i.e. simulates, the corresponding behavior of the physical system it models. Sanders (1976) gives an excellent overview of simulation models and their role in environmental planning. The rapidly growing area of simulation offers numerous exciting links with real-time data acquisition systems. Peart and Barrett (1976) outline several on-going applications which involve using crop ecosystem simulation models to provide a dynamic crop management system. They combine a near real-time environmental data base with a fast-running crop ecosystem simulator to yield information useful to a farm manager for making operational planning decisions. The economic viability of such applications is highly dependent upon the continuous availability of a near real-time data base.

The Black Creek Project has recently installed a real-time data acquisition system to monitor conditions throughout the test area and demonstrate the utility of such a system. Details concerning the selected sensors, data transmission formats and operational characteristics are available elsewhere, Huggins (1975). The intended utilization of the system demonstrates several applications directly relevant to water resource planning and water quality monitoring.

ALERT Configuration

The development of a system designed to accomplish the Acquisition of Local Environmentally Related Trends, ALERT, on the Black Creek project was intended to accomplish two primary objectives: (1) to automate the process of collecting hydrometeorological data from the Black Creek catchment in order to reduce data transcribing delay and labor while expanding the scope of data collected and (2) to demonstrate a real-time acquisition system capable of providing a data base to permit hydrologic simulation of watershed responses concurrently with naturally occuring storm events. An integral part of the second objective involved using the computer to generate operational commands to control pumping samplers which collect periodic water quality samples during a runoff event. The availability of simultaneous data from a network of sensors dispersed over the watershed together with the predictive capabilities of the online computer are intended to improve the fidelity of these water samples. This improved fidelity is anticipated as a result of using short sampling intervals when pollution concentrations are likely to be changing rapidly and much slower sampling rates when conditions are stable. The rapid sampling rates make possible an accurate evaluation of total quantity of pollutants in the runoff while slow rates during stable conditions reduce the number of samples collected and the cost of subsequent laboratory analyses. While the ALERT system was designed to satisfy the objectives of a specific project, the requirements were of such a nature that the resulting system is directly applicable to a large percentage of environmental data acquisition applications.

The specific configuration of the ALERT system can best be described by reference to the block diagram of Figure 1. The remote sensor blocks actually correspond to dispersed locations within the catchment which are each capable of supporting multiple transducers and receiving equipment control commands from the remote computer. Information is transmitted between the central receiver and the remote locations over a closed loop telephone link (solid lines in Figure 1) or battery-powered FM radio telemetry links. The choice between a telephone or radio transmission linkage is determined by the degree of availability of a telephone drop at a given remote site and the distance from the central receiver. The radio transmitters employed are limited to an 8 km radius.

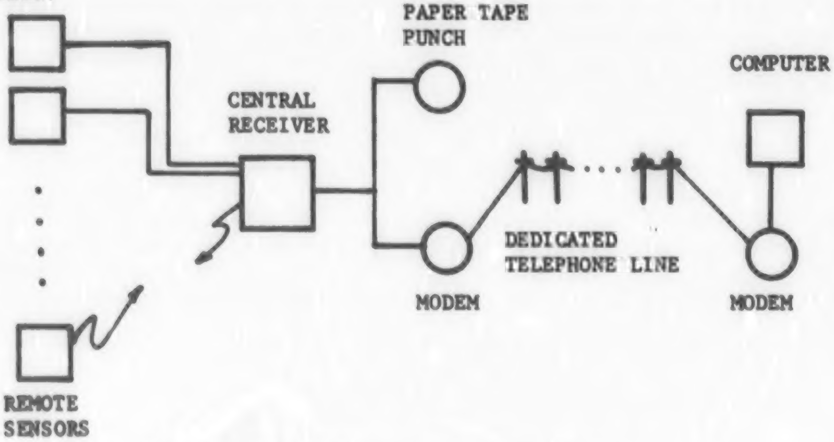

Fig. 1. Block diagram of ALERT system.

Data received by the central station from the remote transducers is simultaneously transferred to two outputs. First, it is presented to a battery operated paper tape punch. Secondly, it is serialized and, through a modem* interface, transmitted over a dedicated telephone line to a remote on-line computer on the Purdue campus approximately 250 km away. The on-site paper punch provides a back-up record and degree of redundancy essential to maintaining a continuous historical data file in the event of interrupted communication with the remote computer. Of course, any real-time analysis and control capability is lost during such conditions.

The on-line computer on the Purdue campus is a minicomputer running a general purpose time-sharing operating system. The Black Creek installation is seen by the computer as simply one of several simultaneous users active on the system. The operating program which controls communication with the Black Creek station has four primary responsibilities: (1) assembling the incoming data into suitable files and permanent storage of these files on magnetic disk and/or tape, (2) maintenance of a dynamic file of the instantaneous level of all variables being monitored in the watershed and the operational status of all transducers, (3) providing a preliminary analysis of water stage data in order to issue feedback control commands to operate the water sampling equipment, and (4) detection of storm conditions in the watershed that indicate the need to activate a complete real-time simulation of the hydrologic behavior of the catchment. During a runoff producing storm, a simulation model is activated which combines historical data files describing physical characteristics of the catchment with real-time, dynamically changing data concerning rainfall intensity distribution and stream stage to estimate height and times of peak flows at all points in the drainage network. If the geographical location warrented such action, the computer could be programmed to automatically ALERT responsible authorities in the event of impending dangerous flood levels.

SUMMARY AND CONCLUSIONS

The collection of comprehensive environmental data is an essential requirement for rational planning of non-point pollution control measures and for subsequent enforcement and post-planning evaluation activities. Several examples of such activities underway in the Black Creek Study Area have been described. The dramatic impact of utilizing real-time computers to collect environmental data has been outlined. Proper transducer selection and data network configuration allow existing time-sharing computer systems to serve as real-time systems for most environmental data requirements with no additional hardware or system level software changes. This approach provides the benefits of an on-line computer with no capital outlay beyond those associated with a data logging system of greatly reduced capability. While operating costs will be slightly higher for the real-time system, these extra costs are primarily proportional to the degree of utilization of the on-line features of the system and are therefore subject to cost/benefit considerations and administrative control. Furthermore, many of these associated benefits are sufficient to significantly influence the economic justification of the network of field transducers required for any degree of automation of data collection procedures.

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*Modem is an acronym for modulator-demodulator. Operating in pairs, these devices provide a standard means of converting the voltage or currents generated and required by computers into tones suitable for transmission over telephone lines.

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DETERMINANTS OF WATER QUALITY IN THE BLACK CREEK WATERSHED

by

James R. Karr* and Daniel R. Dudley**

ABSTRACT

A series of 120 sample locations have been selected within the Black Creek watershed to sample areas of different stream morphology, land use, vegetation cover, and other factors with the objective of a detailed analysis of relationships between these factors and water quality. The short time since initiation of our expanded effort precludes a detailed analysis. Three major stream conditions are identified during a prolonged dry period in the summer of 1976. These three regions are: 1) base flow area maintained by groundwater, 2) intermittent flow zone downstream from Harlan, and 3) dry stream channels with stagnant pools. Groundwater flow had significantly lower turbidity, phosphorus, and ammonia than downstream stations indicating these materials are accumulated from the Black Creek channel rather than being picked up by surface runoff.

Four major regions of stream were selected for comparisons of water quality throughout the watershed. In general, Driesbach Drain carried the largest volumes of sediment and nutrients while Wertz and Smith-Fry Drains contained the lowest concentrations. The main Black Creek channel below Brush College Road was intermediate. Harlan was a major source of nutrients and suspended solids in the watershed. Considerable fine scale variation is evident throughout the watershed and detailed analysis of that variation will be presented in a future report.

A number of channel and tile flow sites were selected for monitoring organic pollution levels in the watershed. In general, highest bacterial counts are associated with Harlan and lowest counts occur in the tributaries such as Wertz and Smith-Fry Drains. Bacterial counts decline downstream in Black Creek. Counts in the nearby Wann Ditch are below those in Black Creek. A number of surface and tile samples throughout the watershed indicate contamination from domestic sources. Fecal coliform/fecal streptococcus ratios indicate that most contamination is from human wastes. Accumulation of organic pollutants in anaerobic sediments suggests that the capacity of the biota to assimilate these materials is being exceeded.

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INTRODUCTION

Declining water quality seems to be an inevitable result of intensification of land use by human society. This decline results from disequilibria in both the terrestrial and aquatic sections of watersheds as well as in the aquatic-terrestrial interface. Signs of these disequilibria are easily recognized and include the following (1):

1. Rapid runoff resulting in drastic fluctuations in stream levels, including both floods and droughts,
2. Large volumes of nutrients and sediments released from terrestrial to aquatic ecosystems, often over short time periods,
3. Increased fluctuations in stream temperatures,
4. Increased streambank erosion as streams attempt to re-establish equilibria by forming pools and riffles and a meandering topography, and
5. Decreased diversity and stability in the biotic component of the aquatic ecosystem.

These consequences are easily predicted when one considers the nature of changes imposed on watersheds by human society. The task of society is to develop management programs which maintain water quality levels without unduly compromising the requirements of high yield agriculture.

Unfortunately, problems arise when management programs and regulations are developed with insufficient knowledge of the detailed dynamics which result in varying water quality. Our present research efforts at Black Creek are designed to clarify the origins of sediments and nutrients and their transport dynamics at the land-water interface. In addition, we have been involved in an examination of the microbiological environment in Black Creek.

WATER SAMPLING STATIONS

From an initial sampling base of 12 stations on a small section of the Wertz Drain (2) we have expanded to an intensive series of 120 sample stations throughout the Black Creek watershed (Figure 1). These stations were selected to allow intensive sampling on four major areas of the watershed.

1. Driesbach Drain. Since the initiation of the Black Creek Sediment Control Project, Driesbach Drain has been the subject of intense efforts to improve agricultural and conservation practices. A series of 20 channel stations between Springfield Center and Brush College Roads has been established to monitor the impact of changes in agricultural and conservation practices on water quality.

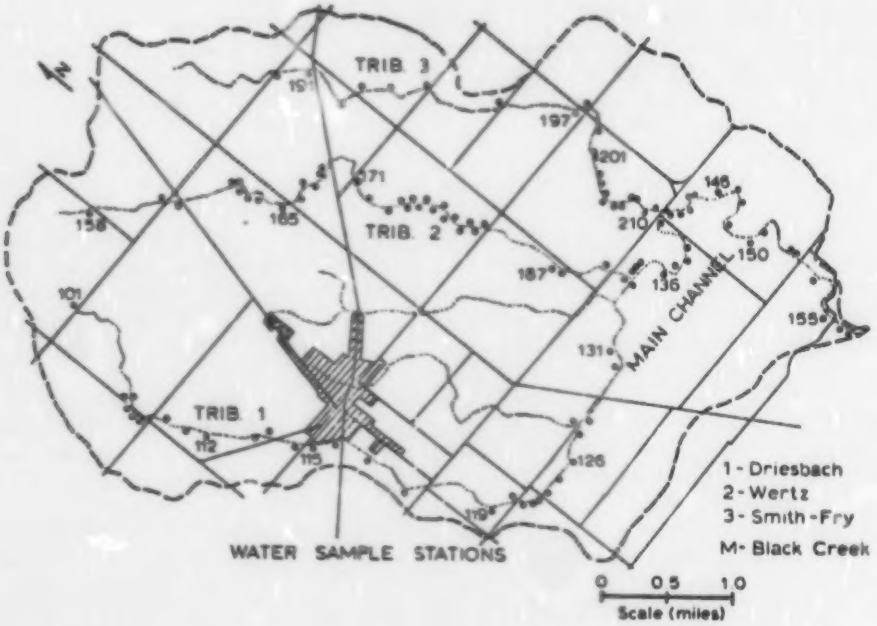
N
TRIB. 3
191
197
201
146
210
150
156
165
171
TRIB. 2
187
136
155
101
131
MAIN CHANNEL
TRIB. 1
112
115
126
119
WATER SAMPLE STATIONS
1 - Driesbach
2 - Wertz
3 - Smith-Fry
M - Black Creek
0
0.5
1.0
Scale (miles)

Figure 1. Map of Black Creek Watershed Showing Location of Water Sample Stations.

2. Wertz Drain. Our original sampling included 12 stations between Knouse and Antwerp Roads. The number of stations in that reach has been expanded to 16 and an additional 18 stations have been located in the remainder of the Wertz Drain between Boger Road and Black Creek. This expansion is designed to clarify the changes in stream quality resulting from several planned conservation activities initiated in the summer of 1976. In addition, we will continue the earlier monitoring efforts in the Wertz Woods area.

3. Smith-Fry Drain. Little or no conservation planning work had been initiated on the Smith-Fry Drain by summer 1976. As a result, water quality in this channel may reflect that of other Black Creek tributaries before initiation of the Black Creek Sediment Control Project. A total of 23 channel stations is located along the Smith-Fry Drain.

4. Black Creek. Thirty-two stations have been located along the Black Creek channel between Brush College Road and the Maumee River. The deeper waters and increasing flow volumes of the Black Creek channel will help to clarify the dynamics of sediment and nutrient movements in larger streams.

In addition to these stations a number of other sites have been selected to measure such areas as tile outflows from fields with and without parallel tile outlet terrace systems. Low runoff volumes during the summer of 1976 prevented studies of the effectiveness of these terrace systems.

The sample sites for this expanded effort have been selected to sample areas of different stream morphology, land use, vegetation cover, and other factors. We are presently developing a system to classify each sample location to allow a detailed quantitative analysis of relationships between these factors and water quality.

In the meantime we have collected water samples every two weeks since early June. Chemical analysis has been completed on all samples taken in the June to August period. Each water sample is analyzed for the following parameters: total alkalinity, specific conductance, total dissolved solids, hardness, turbidity, total phosphorus, soluble orthophosphate, nitrate, nitrite, ammonia, organic nitrogen, total residue (suspended solids), and sulfate.

In addition to these activities we routinely monitor the microbiological conditions in surface waters and tile flows throughout the watershed. Samples for microbiological studies were collected at these stations on March 29, June 7, and August 23.

Finally, we have continued monitoring fish populations throughout the watershed. However, because of limited time and space we will not discuss the results of the fish studies in the present report. This report includes information on three components of our study in 1976: 1) condition of the Black Creek watershed; 2) variation in water quality; and 3) microbiological assays in spring and summer.

CONDITION OF THE WATERSHED

The Black Creek watershed experienced a prolonged dry period this past summer. Rainfall events were generally less than one inch and were quickly absorbed by dry soil resulting in very little or no surface runoff. Most suspended solids and nutrients carried in Black Creek were from within streams, drain tiles, and domestic sewage sources. Furthermore, by late summer most of the streams in the watershed were reduced to isolated pools with no surface flow.

Because of the low flow conditions on the Black Creek watershed during July, August, and September it is possible to divide the watershed into several distinct units (Figure 2). The lower reaches of Black Creek had a base flow maintained by groundwater all summer. Estimated flow rates during these base flow conditions ranged from 0.0005 to 0.0040 m^3/sec. Most of the water for this flow originates at two distinct locations; Gorrell Drain at Notestine Road and about 150 m downstream from station 131 (east of Bull Rapids Road on Black Creek). Water samples of this outflow reflect lower phosphorus, ammonia, and turbidity levels than found at downstream stations (Table 1). Data for Table 1 were collected on August 24 and 25 after a period of at least one week without flows from any tributary drain or from the upper reaches

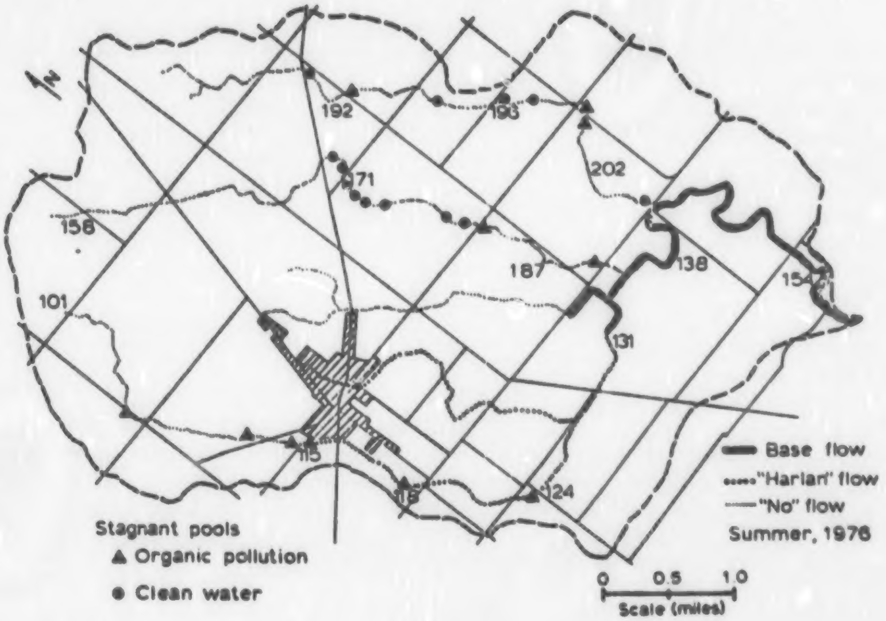

Figure 2. Map Indicating Three Major Stream Conditions in the Black Creek Watershed During the Summer of 1976.

of Black Creek. Since there was no surface runoff or upstream channel flow, the changes in water chemistry indicated by Table 1 result from the accumulation of materials from the stream channel and riparian environment of Black Creek. A hog watering facility a short distance above station 132 may have been responsible for some of the changes in concentrations of some nutrients. Unfortunately, we did not have any sample stations between the groundwater source and the hog lot.

Two other sources of pollutants in the lower section of Black Creek were tile lines near stations 140 and 154 which carried domestic sewage effluent. No significant shifts in water chemistry could be detected at these locations, suggesting that these sources are generally of little consequence in affecting water chemistry.

Immediately following the few rainfall events of summer 1976 Driesbach and Richelderfer Drains experienced increased runoff rates while other tributaries were little affected by the rains. These intermittent flows identify a second major area of the watershed: areas with very low flow or intermittent flow through most of the summer but with an occasional spate originating in Harlan (Figure 2). We do not have any regular sampling stations on Richelderfer Drain near Harlan but a series of stations on Driesbach Drain yield interesting results. Virtually all water chemistry parameters increase sharply as the stream

Table 1. Chemical Characteristics of Groundwater and Channel Flows in the Lower Segments of Black Creek, August 24 and 25, 197[illegible]

Parameter[c]	Groundwater	Channel Flow[a]
Alkalinity	267	268.7 ± 6.35
Conductivity	702	783.7 ± 35.01
Dissolved Solids	512	571.3 ± 25.00
Hardness	357	358.3 ± 3.51
Turbidity	27	58.0 ± 4.00[b]
Total Phosphorus	0.047	0.64 ± 0.02[b]
Soluble Orthophosphate	0.003	0.04 ± 0.008[b]
Nitrate	0.01	0.01
Nitrite	0.01	0.01
Ammonia	0.01	0.087 ± 0.005[b]
Organic Nitrogen	0.29	0.313 ± 0.095
Total Residue (Suspended Solids)	532	578.7 22.7
Sulfate	88.1	88.8 1.15

[a] Stations 132-134, Mean ± standard deviation

[b] Groundwater and channel flow concentrations significantly different at $p<0.05$

[c] mg/l except turbidity in Jackson Turbidity Units

passes Harlan (Stations 115 and 116). As the stream continues south beyond Harlan all parameters decline and reach levels similar to those above Harlan. This generally happens at or slightly below station 118 about 1 km south of Harlan. This seems to be a result of settling out of organic matter between stations 115 and 118. Apparently, this particulate matter cannot be metabolized by the stream ecosystem during low flow periods. It accumulates in anaerobic sediments and is later washed downstream during rainfall events (see discussion of microbiological sampling below). It is significant that a population of fish is able to persist at station 118 but very few persist above that sample station.

The dynamics of nutrients in this section of stream are less clear. Perhaps the decline in nutrients is due to incorporation into algal biomass, which settles to the bottom. It is then flushed out with other organic matter during runoff events.

Observations of Richelderfer Drain in late September and October (water samples not yet analyzed) indicate that channel flow from Harlan is considerably more turbid than that in the main Black Creek channel.

The third major situation in the watershed existed upstream of Harlan on the Driesbach and throughout Wertz and Smith-Fry Drains. Generally, flow conditions in these areas were very low or stagnant. Upper Driesbach (above station 113) remained dry through much of the summer (Table 2). Some flow occurred in Smith-Fry Drain in late June and July and flow rates in Wertz Drain were lower and more intermittent. Most areas along the tributaries were reduced to standing pools many of which dried up completely by the end of summer. This resulted in progressive concentration of fishes and ultimately death for many as habitat

Table 2. Number of Stations Without Water During the Summer Sample Periods on Driesbach Drain, 1976

Stream Segment	Total Number of Stations	No. of Stations Without Water On June 10	June 29	July 13	July 26	Aug 9	Aug 24
Upper Segment (Springfield Center to Antwerp Roads)	11	2	4	8	9	9	10
Lower Segment	9	0	0	0	1	0	4

deterioration made them especially susceptible to raccoon and other predators. The most severe condition occurred in early September when the isolated pools could be classed into two groups. Many pools were maintained by tile flows which commonly contained significant amounts of organic effluents (Figure 2). Pools in areas not receiving such effluent maintained relatively better water quality.

VARIATIONS IN WATER QUALITY

As demonstrated by earlier studies of the Wertz Woods area (2), local variation in streamside vegetation, channel morphology, and land use affect water quality characteristics. Our expanded study, although preliminary and limited by low flows in the summer of 1976, substantiate that conclusion.

Over the next year we shall continue our collections of data in an effort to clarify quantitative relationships between water quality and land use and land form. The following discussions demonstrate that complex and intriguing patterns of variation among subareas of the watershed which result in varying water quality.

Suspended Solids

Suspended solids content of Black Creek declines in the first 3 km downstream from Brush College Road. After this decline from 800 to 600 ppm, suspended solids concentrations remain rather constant to the Maumee River. In subsequent discussion we shall refer to the average level in the main Black Creek channel as our "Index Value" (see dashed line in Figure 3). This "Index Value" will be used to compare, qualitatively, the four major segments of the watershed. For example, with an index of 600 in Black Creek, it is clear that most values in Driesbach Drain are above the index (Figure 4). Note also that the values increase abruptly as the stream reaches Harlan, but decline downstream from Harlan. In both the Wertz and Smith-Fry Drains upstream values are above the index while middle and lower reaches tend to remain below the index value for suspended solids (Figures 5 and 6). This general pattern is found in all three tributaries for most water quality parameters. However, it is less obvious in data from the Driesbach Drain where a large spike occurs for most parameters when the stream reaches Harlan.

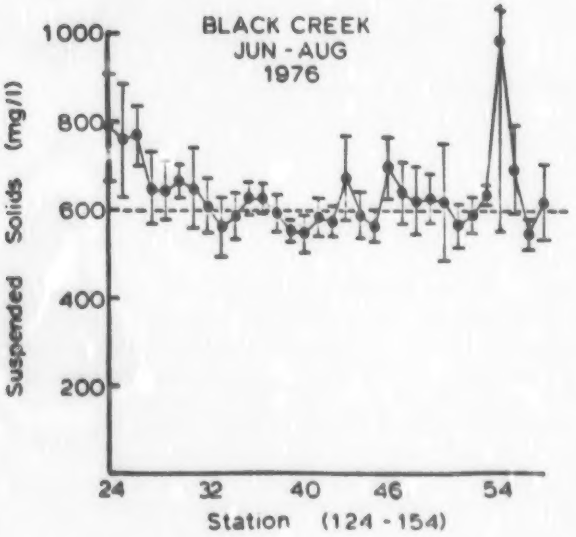

Figure 3. Mean and Standard Error of Mean for Suspended Solids Loads in Black Creek

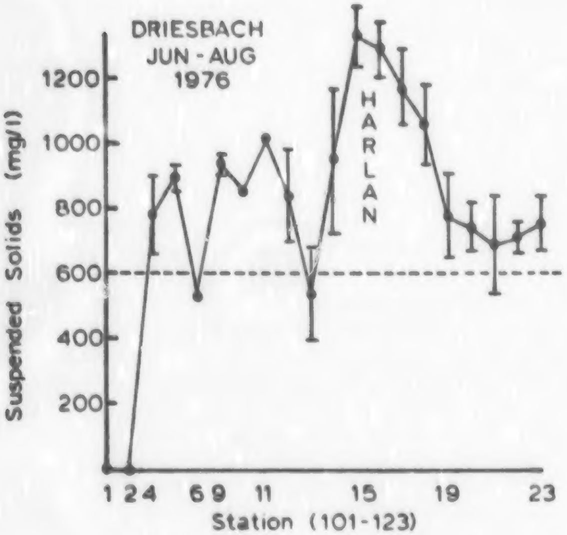

Figure 4. Mean and Standard Error of Mean For Suspended Solids Load in Driesbach Drain

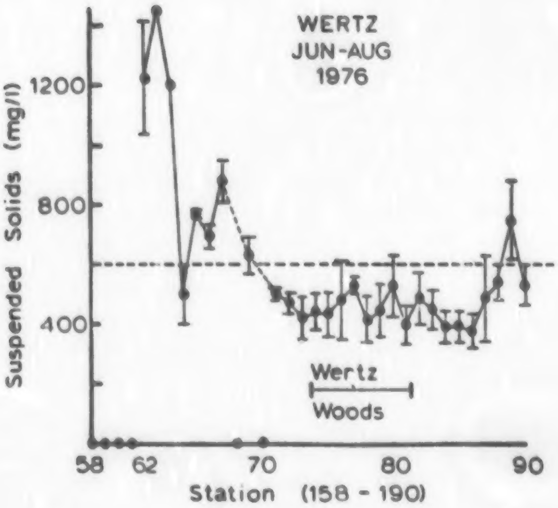

Figure 5. Mean and Standard Error of Mean for Suspended Solids Loads in Wertz Drain

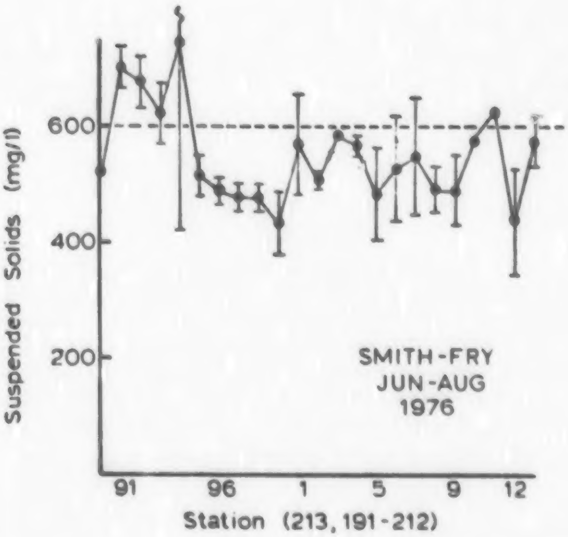

Figure 6. Mean and Standard Error of Mean for Suspended Solids Loads in Smith-Fry Drain

The significance of small scale variation in water quality parameters is demonstrated by sample station 189 at the lower end of the Wertz Drain (Figure 5). Suspended solids loads at 189 are about 200 mg/l above the two nearest stations. A small farm pond adjacent to the stream supports several domestic ducks. These ducks frequently travel to the adjacent channel to feed. Their feeding activities increase the suspended solids load of the stream.

Phosphorus

Two phosphorus parameters are measured for all water samples: total phosphorus and orthophosphate. For both, concentrations decline downstream in Black Creek (Table 3). Relative to the Black Creek segment, concentrations are low to very low in Wertz and Smith-Fry Drains but high in Driesbach Drain. Phosphorus spikes are especially high at Harlan where they are 10 to 100 times higher than the index value for total phosphorus and soluble orthophosphate, respectively.

Nitrogen

Routine analyses include evaluations of four forms of nitrogen (Table 3). Nitrate and nitrite levels are constant in Black Creek while ammonia and organic nitrogen decline downstream. All four forms of nitrogen are much higher than the index value in Driesbach Drain. Nitrate and nitrite forms tend to be higher than index values in Wertz and Smith-Fry Drains but ammonia and organic nitrogen are generally lower. High spikes also occur in upstream areas and at Harlan.

Turbidity and Total Residue

Turbidity levels do not change significantly between Driesbach Drain and Black Creek (Table 3). Turbidity levels in the two other tributaries (Wertz and Smith-Fry) are below those for the lower Black Creek index value. Similarly, for total residue the two tributaries are below those in the main Black Creek channel. Driesbach Drain levels are above those in the index stream.

Other Parameters

Five other parameters are included in our analysis (Table 3). Three (alkalinity, conductivity, and dissolved solids) have significantly decreasing trends in the lower segment of the watershed. Two other parameters (hardness and sulfate) are relatively stable in the index area. All five are in high concentrations in Driesbach Drain. Conductivity, dissolved solids, and sulfate are low in the Wertz and Smith-Fry sample areas. Alkalinity and hardness are near or above their respective index values in the tributary streams.

MICROBIOLOGICAL DATA

The distribution of microbiological samples is shown in Figure 7. Flow conditions for the first two samples (March 29 and June 7) were near the seasonal normals while the August samples (August 23) were

Table 3. Relative Water Quality Characteristics in the Major Study Segments of the Black Creek Watershed, June-July, 1976

Parameter	Stream Segment				Index
	Driesbach	Wertz	Smith-Fry	Black Creek	Value
Phosphorus					
Total Phosphorus	High	Low	Very Low	I (D)	0.70
Soluble Orthophosphate	High	Very Low	Very Low	I (D)	0.15
Nitrogen					
Nitrate	Very High	Very High	High	I	0.01
Nitrite	Very High	I	High	I	0.03
Ammonia	Very High	Low	Low	I (D)	0.40
Organic Nitrogen	Very High	I	Low	I (D)	0.50
Other Parameters					
Turbidity	I	Low	Low	I	50
Total Residue (Susp. Solids)	High	Low	Low	I	600
Alkalinity	High	High	I	I (D)	140
Hardness	High	I	High	I	220
Conductivity	High	Low	Low	I (D)	700
Dissolved Solids	High	Low	Low	I (D)	500
Sulfate	High	Low	Low	I	30

collected during a period of very low flows. The number of stream stations without flowing water was 6 for both the March and June samples and 11 for August. The number of tiles without flow in the three months were 0, 6, and 14.

The small number of samples severely limited detailed analysis of organic pollutants in the Black Creek watershed. It is possible, however, to detect some general patterns with available data.

Stream Samples

Nineteen sample sites can be grouped into seven sets that reflect ecological and/or geographical affinity groups (Table 4). The results from all stations within each group are averaged over all samples. Since there is considerable variation among sample periods the data in Table 7 should be considered order of magnitude approximations.

The only station located upstream from Harlan shows evidence of domestic pollution. The presumed source is a tile line just upstream of station 304. In general, it appears that the upper portion of the Driesbach Drain receives greater overall organic contamination than any portion of the Wertz or Smith-Fry Drains.

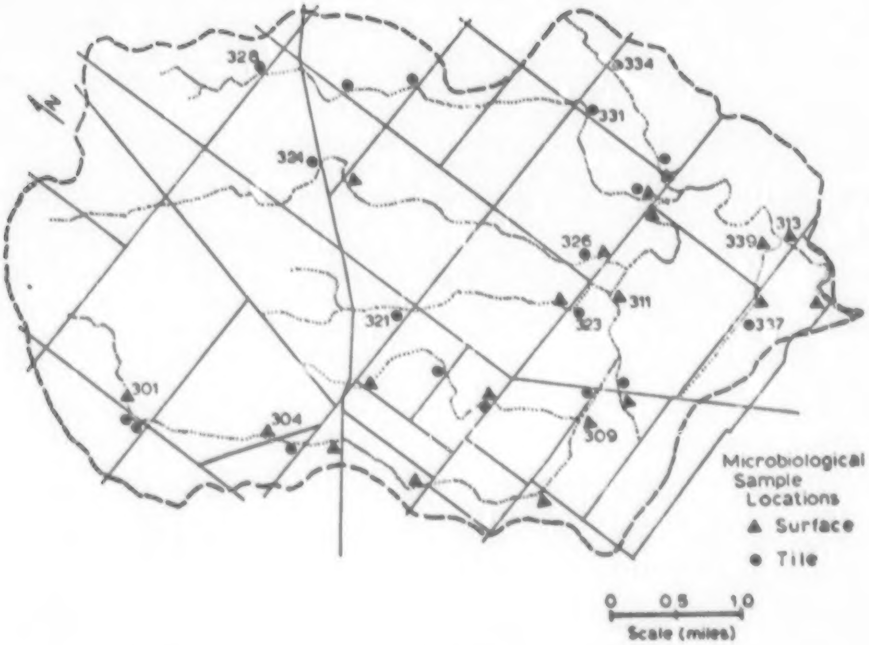

Figure 7. Map of Black Creek Watershed Showing Microbiological Sampling Locations

Total coliform counts from samples at Harlan increase by 50 X over levels at the upstream station on the Driesbach. Data indicate higher levels of contamination on the Richelderfer, especially for fecal counts, than in the Driesbach. The Richelderfer undoubtedly receives more wastes than does the Driesbach. The majority of the flow entering the Driesbach at Harlan receives some secondary treatment at a small sewage treatment facility associated with a trailer park.

Downstream from Harlan in the intermittent flow zone fecal counts decrease rapidly, although total coliforms remains rather high. Bacterial levels continue to decline in the base flow area of the lower Black Creek. A station at Black Creek and Ward Road showed unusually high total coliform counts although the reason is not clear. In lower Black Creek fecal streptococcus occur only at stations (312 and 314) below known domestic sewage outfalls.

Stations located on tributary drains without nearby (upstream) sources of organic pollution have counts similar to stations along lower Black Creek. Two stations on tributary drains (322, 327) have bacterial contamination levels near those of Harlan. They are associated with sources of organic pollution.

Wann Ditch east of the watershed had total coliform counts well below those of Black Creek. Total coliform counts from the Maumee

Table 4. Mean Bacterial Counts for Seven "Affinity Groups", March to August, 1976

Location	Number of Stations	Total Coliforms	Fecal Coliforms	Fecal Streptococcus
Driesbach Drain above Harlan	1	6,250[a]	4,600	300
Driesbach and Richelderfer at Harlan	2	309,000	317,000[b]	157,000[b]
Intermittent Flow Zone downstream from Harlan	4	15,100	640	340
Base Flow Zone Lower Black Creek	4	11,200	330	150
Tributary Drains w/o Organic Pollution	6	2,800	740	250
Wann Ditch	1	1,200	230	<100
Maumee River	1	11,000	1,500	<100

a Coliforms per 100 ml

b August counts unusually high (by 10X)

River were near those in the lower reaches of Black Creek. Fecal coliform counts were higher in the Maumee River than in Black Creek. We can only speculate on the sources of contamination in the Maumee River.

Tile Samples

Twenty tile lines are sampled routinely in the microbiological survey. It is more difficult to extract meaningful results from the tile data than from the surface flows discussed above. A number of stations (305, 310, 318, 329, 331) are obviously influenced by domestic sources of pollution. Mean bacterial counts for these stations were 4×10^5 for total coliform, 5×10^4 for fecal coliforms and 3×10^4 for fecal streptococcus. Early samples at station 330 were heavily contaminated with fecal coliforms but this line did not flow through most of the summer.

Other sites (302, 324, 334, 337) had lower levels (below 10^3) of fecal coliform and/or fecal streptococcus. These levels of contamination seemed without pattern. Many sites with low bacterial counts in March and June were not flowing in August. Remaining tiles showed no evidence of organic pollution.

From March to June bacterial counts declined at 7 stations, increased at 2, and 5 were not flowing at the time of June samples. Thus low flows generally resulted in fewer total coliforms in tile effluents.

In summary, our surveys show significant pollution levels, in and downstream from Harlan. Waters in lower Black Creek, Wertz Drain, and Smith-Fry Drain had lower levels of contamination. In addition to the major sources of organic pollution from Harlan contaminants originating from rural sources are also present at no less than 20 other localities within the watershed.

Organic pollution throughout the Black Creek watershed is well above EPA guideline levels indicating possible health hazards. Furthermore, fecal coliform/fecal streptococcus ratios are generally above 2.0, indicating that most effluent is from human wastes. This certainly affects the water quality and biotic communities of Black Creek. Extreme low flow conditions in August 1976 probably lessened the impact of Harlan's effluents on the lower reaches of Black Creek. However, the lack of flow to flush streams magnified the problem of organic pollution in the vicinity of Harlan. Minor spates in September and October flushed Driesbach and Richelderfer Drains, and thereby, alleviated some of the pollution problem in the intermittent flow zone. During the low flow conditions prevailing in 1976 the effects of domestic pollution were irregular in many parts of the watershed.

Significant build-ups of organic material in anaerobic sediments found in the upper watershed suggest that the biotic systems of Black Creek cannot assimilate or break down the quantities of organic material discharged into Black Creek. This seems to be true despite the flushing and scouring action of runoff events.

ACKNOWLEDGMENTS

O. Gorman, P. Angermeier, A. Gora, D. Ratcliffe, and K. O'Halloran helped with the often tedious field and laboratory studies involved with this project. B. Jones helped in preparation of computer programs for analysis and graphical presentation of water quality data. Chemical analysis of water samples was conducted at the Water Quality Laboratory of the Illinois Natural History Survey under the direction of Dr. A. Brigham. Microbiological assays were done by the Allen County Board of Health. Without the technical assistance of all these persons and agencies this study would not have been possible.

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CULTURALLY INDUCED ACCELERATION OF MASS WASTAGE ON RED CLAY SLOPES, LITTLE BALSAM CREEK, DOUGLAS CO., WISCONSIN

by

J. T. Mengel Jr.[1], and B. E. Brown[2]

GEOLOGY

General Statement

The Little Balsam Creek drainage was selected for investigation in the hope that it was representative, within a limited area, of many of the geologic and engineering conditions in the Nemadji River watershed and other parts of the red clay plain which borders the southwestern side of Lake Superior. Data in this report proves that it is representative of the Douglas County portion of the Superior plain and it is probable that the conclusions reached here are applicable to much of the remainder of the plain in Michigan, Wisconsin, and Minnesota.

In Douglas County, Wisconsin the altitude of the Superior plain ranges from about 625 feet above mean sea level along the Lake to about 1100 feet along the South Range, a sand covered highland with a lava bed rock core which is the south boundary of the red clay area (Figure 1). The plain is underlain by glacially derived materials consisting of a thick surface layer of red brown and associated grayish clays and brown sands, which rest on a vaguely stratified clay layer which contains large but variable amounts of silt, sand, gravel, and coarser material. These Quaternary age sediments are underlain, in turn, by red sandstones or black basaltic lava flows of Late Precambrian (Keweenawan) age.

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The Quaternary age sediments accumulated between about 9,000 and 12,000 years ago at a time when the last continental glacier to cover the region was retreating but still filled the eastern end of the Lake Superior basin, impounding high level lakes in the west end (Farrand, 1969). The floor of these high level lakes, now the gently north or east sloping surface of the Superior plain is being dissected by a stream system which has cut steep-sided valleys in the underlying sediments, and in some cases removed them entirely, exposing the Precambrian age rocks beneath. The Little Balsam Creek and other parts of the drainage system is in a geologically youthful stage of evolution and is undergoing the kind of valley widening and deepening characteristic of such a stage.

Stratigraphic Succession

In the Little Balsam Creek drainage, south of the 1050 foot topographic contour, the stratigraphic succession within about 30 feet of the upland surface is fine to medium brown colored sand with some silt and gravel. Mappable stratigraphic subdivisions cannot be identified in this unit. A somewhat similar sequence of sands is present along the South Range in most localities marginal to the red clay area. The sands are above the level of strong high level lake action and exhibit a knob and kettle or channeled outwash topography which contrasts sharply with the smooth upland surface of the Superior red clay plain below an elevation of about 1100 feet. In the Little Balsam area the sand sequence grades laterally into the clays of the plain indicating their contemporaneous deposition.

North of the 950 foot topographic contour in the Little Balsam drainage the gently and smoothly rolling upland surface of the plain is underlain by a red brown clay layer up to about 25 feet thick. A gray brown or brownish gray clay of equal or somewhat greater thickness underlies the red unit. Limited amounts of silt, sand, pea-size gravel and cobbles or boulders are present in both these clay units. The lowest part of the gray brown unit shows distinct varves where it crops out in the Balsam Creek drainage. The Atterberg Limit tests data does not indicate any obvious mechanical difference between these two clay units which are the main slope-forming materials in the area. Similar clays underlie the surface of the Superior plain in most localities.

Slope Profiles

Slope basal angles are in the range 7-17° in the lower valley of the Little Balsam (i.e., north of the 950 foot topographic contour) and are usually over 25° in the upper valley, south of the 950 contour. South of the 950 foot elevation the slopes are underlain by the sand unit and typically exhibit convex profiles with little or no evidence of failure. No study was made of this portion of the drainage since no red clays occur here.

North of the 950 foot elevation slopes are underlain mainly by clays and show evidence of flow and sliding almost everywhere. Tributary valleys have nearly straight to slightly convex valley wall profiles. Movement is particularly evident on slopes with basal angles greater than about 10 degrees and a rise of more than about 10 feet above the valley bottom. Flow of red clay downslope over the gray brown clay is widespread and most slopes north of the 950 foot contour show red clay as their surface material.

The Little Balsam has a valley wall profile which is mildly to strongly convex near its toe and mildly to markedly concave near the upland surface. A very steep inclination or a raw notch is typical at the toe of any slope along the lower valley of the Little Balsam. This toe steepening is due to clay falls triggered by stream undercutting. The presence of dessication cracks and of several sets of high angle joints in the clay provide natural directions of weakness for such failure.

Toe undercutting triggers movement of the bank surface which may extend far up slope and involve piecemeal movement of the entire surface. The depth of the sliding mass rarely exceeds 5-7 feet and does not involve the entire valley wall, only its surface. Movement is mainly translational downslope rather than rotational into the slope. Small scale rotational slump along shallow arcs is common especially at the toe and the crest of the more active slopes.

The failure surfaces pass beneath the depth of development of the root systems of even the larger trees now present in the area. It is probable that vegetation capable of protecting the toe of slopes from stream erosion and vegetation capable of preventing excessive drying out of the slope surface will prove to be more important in the prevention of sliding, than that serving mainly to bind the surface layer together.

A man who grew up in the Little Balsam drainage a half a century ago mourned the loss of the trout ponds which were present in his youth. These ponds had been created by log jams which resulted from lumbering wastes. The loss of the ponds places the triggering of the latest round of accelerated slope failure through general valley deepening within the lifetime of those now living. This observation is reinforced by study of conditions elsewhere in the red clay area which indicate that a combination of timber removal and upland drainage improvement for agricultural purposes has upset the previously established relationship between slopes and stream erosion. Toe protection can probably still help reduce clay loss from some slopes, but in most cases where recent stream downcutting and toe undermining is already advanced, such measures will be of little help because such slopes already contain numerous fractures which allow easy water penetration and the slopes lack necessary toe support.

MECHANICAL PROPERTIES OF RED CLAY

Angle of Internal Friction

Undrained triaxial shear tests run at a slow rate (6 hours to obtain failure) on three sets of core samples taken in the NE 1/4, Sec. 36-T.49N-R.14W are perhaps the best data currently available from which values of internal friction angles (ϕ angles) and cohesion can be obtained.

Table I.

Depth (ft.)	ϕ	$\bar{\phi}$	$c = \bar{c}$
12-14	12.5	17	.05kg/cm^2
32-34	9.0	14	.20kg/cm^2
80-82	8.5	9.5	.35kg/cm^2

where: ϕ = angle of internal friction (total stress)
$\bar{\phi}$ = angle of internal friction (effective stress)
$c = \bar{c}$ cohesion

Construction site data give internal friction angles ranging from a low of 11 degrees to a high of 32 degrees. Present data suggest that an internal friction angle of about 18 to 20 degrees for the effective state is a reasonable assumption. Based on long term natural slope angles, an internal friction angle about half as great is indicated for the total stress state. More study is needed to establish regional variations in materials and to associate internal friction angles with particular stratigraphic units.

Clay Density and Moisture Content

The dry weight of red clay is typically in the range from 70 to 83 pounds per cubic foot and averages about 78 pounds. The natural moisture content of the clay, expressed as a percentage of the dry weight, is typically in the range from 29 to 50 percent and averages about 39 percent. Use of these average figures gives a unit weight of about 108 pounds per cubic foot as representative of the clay.

The Wisconsin Department of Transportation uses 120 pounds per cubic foot as an average value for bulk clay in the natural state in well drained areas being considered as possible borrow sites. Because of the presence of scattered pebbles, cobbles, boulders and other variability which cannot be sampled this value is probably more representative of actual bulk conditions than the 108 pound one.

Moisture content influences the unit weight of the clay and is a factor in determining slope stability. A moisture content 20% higher than is typical would add an additional 16 pounds per cubic foot, assuming a dry weight of 78 pounds, or using the Department of Transportation value of 90 pounds for the bulk clay, an additional 18 pounds per cubic foot. Since moisture content in the 55 to 65 percent range has been measured in several slide localities and in several non slide areas in the present investigation, it is probable that weights in the 124-138 pound range are not uncommon and should be allowed for in slope design.

In addition, laboratory determinations of moisture cannot take into account the highly variable conditions in the surface zone about 5-7 feet deep where open shrinkage cracks and joints are present. Ten percent open space in this zone, if filled with water, would add about 6 additional pounds per cubic foot to the values cited above. Since this zone is the one in, or at the base of, which most down slope movement takes place slope stability calculations should make allowance for soil weights to reach the 130-145 pound per cubic foot range during wet intervals.

The relationship of moisture content to depth, as determined from samples obtained by auger boring is shown in Figure 2. From this plot it can be seen that the moisture content of the clays in the first 10 feet of depth beneath the upland surface is apt to be in the 27-35% range and that below this depth moisture content is apt to be higher, averaging over 40%. Although there is no free water table in the clay units anywhere in the red clay district, Figure 2 shows that there is a considerable stabilization of the rate of change of water content below depths of about 10 feet.

Clay Consistency

The moisture content at which clay passes from one physical state to another are shown by empirical parameters known as Atterberg Limits. The two most commonly determined are the Plastic Limit and the Liquid Limit, which together define the range of moisture content through which the clay behaves plastically. At moisture contents less than the Plastic Limit the clay behaves as a brittle solid; at moisture contents higher than the Liquid Limit the clay will flow under its own weight. The difference between the Plastic Limit and the Liquid Limit is the Plasticity Index of the clay.

Index and Limit data are useful to classify clays which in hand samples appear to be very similar. Little Balsam and other Douglas County red clays are classified according to the Unified Soil Classification into the major groups CL and CH (Figure 3). Data throughout the area closely follow the straight line PI = .88(LL-18). The clays are inorganic and range from low to high plasticity. With increasing silt content these clays grade into groups ML and MH and it would be possible to select thin layers in the red or grayish clay units which would fall into these categories although almost all of the thickness of the clay sequence is in either the CL or CH group.

The Plastic Limit of the Little Balsam samples tested is typically in the range from 20 to 32%. Comparison of this data with the previously cited data on moisture content indicates that clay within about 5-10 feet of the surface of the ground will tend to behave as a brittle solid and be capable of maintaining open fissures for considerable periods of time, thus giving it an entirely different mechanical character than the plastic clays at depth. Penetration of water to the depth at which plastic flow closes fissures may create a very low strength zone at this depth as can be seen during some seasons of the year along the raw clay slopes bordering Lake Superior. Such a low strength zone may serve as a decollement surface along which the overlying stronger materials slide. Conversely since dessication fissures do not close upon rewetting, moisture collecting in the fissure system above the zone of plasticity may gradually, within a few months to several years, render the upper layer mobile and promote plastic flow or even development of local mud flow on any part of a hillslope.

The Plastic Limit is only moderately influenced by increasing total clay content or by increasing clay content in the -.2 micron size range, although it is more influenced by the percentage of montmorillonite.

The Liquid Limit of the Little Balsam samples tested is typically in the range 40-80%. Comparison of this data with that on the moisture content of the clay shows that situations where the clay will flow under its own weight are to be regarded as common. The Liquid Limit is strongly influenced by increasing total clay content in a sample and is particularly highly influenced by the amount of montmorillonite present. This relation is shown in Figure 4.

The Plasticity Index is typically in the 15-55% range. As with the other Limits, montmorillonite content particularly influences the Plasticity Index (Figure 5). Additional study should be directed toward understanding more about the type of montmorillonite present and what changes in its cation content may influence its mechanical properties.

Tests of the free swelling characteristics of the red clays indicate that the clays have a "moderate" swelling capacity corresponding to a volume change of 20 to 40%. Swelling has not been recognized as an engineering problem in the area but the capacity to swell and the frost heave (several tenths of a foot) are factors promoting the widespread occurrence of down slope plastic creep throughout the area.

Clay Strength

Hand penetrometer strength data for the red clays of the Douglas County red clay area is such that at most construction sites the strength ranges from about .75 to 3 tons per square foot (TSF) and averages about 1 TSF or a little more. An "average" strength has little meaning because of the stepwise variation of strength with depth such as can be seen in Figure 6.

The profile of Figure 6 makes evident the fact that throughout the red clay area from low elevation to high and from east to west the red clays exhibit a near surface zone no more than perhaps 10 feet thick in which average strength is substantially, sometimes as much as 2 or 3 times, greater than it is at depth. The existence of this near surface zone is the reason why most slope failure is superficial in nature and is highly sensitive to slope toe erosion. Because moisture can penetrate the upper surface of this brittle and broken zone tree and other roots are concentrated in it at shallow depth.

The cover of the clay surface influences its strength and consistency. A sandy road bed, a marshy low on the upland, or thick organic soil cover softens the surface, lowering the strength to well below that which obtains at depths a few feet greater. Roadsides and fields with thin grass cover show a near-surface crust having penetrometer strength in excess of 4 TSF.

Any action which tends to promote drying of the red clay surface has the possibility of changing the mechanical behavior of the clays from a more plastic to a more brittle state, thereby changing the type and rate of gravity transport down slope -- plastic creep giving way to sliding and flow of a surficial zone. Since the changes which promote drying also tend to change the rapidity and amount of run off, thereby quickening stream flow and increasing its lateral and vertical erosive capacity, the entire natural equilibrium between streams and bank materials is altered, even in localities where natural cover remains along some portions of a stream course. Although questions remain to be answered and linkages demonstrated quantitatively it is probable that this model approximates events in the Douglas County red clay area. It must also be remembered that any such clays will be slow to develop by human standards and will be affected by longer term climatic variations. Changes in any part of the drainage basin are apt to influence all other parts over a period of time.

The relationship between clay moisture content and strength is shown in Figure 7. There is apparently a nearly linear and drastic decline of strength with increasing moisture content in the range from about 28-35% moisture -- which overlaps with the upper half of the Plastic Limit range (20-32%). Thus there is a linkage between the strength and the consistency of the clay -- high strengths coinciding with brittle behavior and lower strength with plastic behavior. There is a nearly linear, but far more gradual, decrease in strength as the moisture content increases from about 35 to 65%. This is the moisture content/strength which is typical of the vast bulk of the clay sequence in the subsurface.

The red clay sequence cannot be considered to be a single depositional unit, as has been indicated before and is clearly seen in the strength variation w/depth. Such stratigraphic units are doubtless systematic in their distribution and future drilling should seek to outline their extent, thickness and strength because it is by such efforts that the red clay plain can be divided into districts within which particular types of slope ordinances may be applicable and certain types of engineering behavior are indicated.

MINERALOGY OF THE RED CLAY

The nature and behavior of the Red Clay material is determined principally by the nature of the material and by the nature of conditions which have been imposed upon it. This portion of the investigation has as its purpose the determination of the sizes and types of minerals which make up the Red Clay aggregate. Interpretations regarding mechanical behavior, geologic and geographic uniformity of the material, can be made from such mineral and size distribution data.

Mineral Determination and Size Distribution Methods

Separation and Particle Size Distribution: Selected samples from the drilling in the Little Balsam Creek location and from along the south shore of Lake Superior make a group of 15 samples upon which mineralogical analyses were run. Because we were interested in a complete picture of the particle size distribution and because particle size segregation also segregates certain mineral species each sample was split into six particle size ranges which were: sand (>44μ), coarse silt (44-20μ), medium silt (20-5μ), fine silt (5-2μ), coarse clay (2μ-0.2μ), and fine clay (<0.2μ).

In order to facilitate dispersion, to improve the x-ray diffraction results, and to determine the amount of pigmenting iron oxide material, the clays were first subjected to an iron oxide removal process that reduces and complexes the iron in a neutral solution (Aguilera and Jackson, 1953). The samples were dispersed with a Calgon dispersant (sodium hexametaphosphate). Sand was separated with a wet sieving procedure, the silts, using settling decantation techniques, and the clays using centrifuge washing techniques after the methods outlined by Jackson (1956, p. 101). The particle sizes were also determined independently using a settling, pipette withdrawal method as outlined by Volk (p. 37, 1974).

X-ray Diffraction Procedures for Non-Clay Minerals: An internal standard procedure such as described by Azaroff (1968, p. 518) was used for the minerals quartz, potassium and plagioclase feldspars, and calcite and dolomite. This procedure requires the addition of a known substance as a constant weight fraction of a series of standard mixtures and as a similar constant weight fraction of the unknown samples.

Calcite and dolomite were determined by measurement of the CO_2 volume evolved when the sample was immersed in acid. A weighted sample was introduced into a flask, acid was added, and the CO_2 volume measured at ambient temperature and pressure. After correction to STP this could be converted to percent calcite or dolomite. The x-ray diffraction results were modified to conform to the gasometric data. In general the agreement between the x-ray results and the gasometric results was good in terms of total carbonate.

Clay Mineral Determination: The following clay minerals were identified on the following basis:

1) smectite: identified on the basis of a d spacing of 17A in the presence of ethylene glycol. (Smectite is the group name for minerals that expand upon solvation. Montmorillonite is considered to be a member of this wider group.)
2) clay mica or illite: identified on the basis of a d spacing of 10A and 3.33A which was non-expandable in the presence of glycol.
3) chlorite: identified by the presence of a series of basal orders, at d = 14A, 7A, 3.5A, 2.8A, with the line at 7A the strongest of the group. The 14A line is heat stable but upon heating above 500°C the 14A line becomes more intense than the 7A line. This is diagnostic behavior for chlorite.
4) kaolinite: This component, if present, is masked by the presence of chlorite. The (003) line of kaolinite at 2.4A can be diagnostic since it has significant intensity, while the (006) of chlorite at the same position does not usually have significant intensity. The presence of kaolinite is reported where a line at 2.4A appears. Kaolinite in any case does not appear to be a significant component of this material.

Vermiculite and interstratified materials, although certainly present in small amounts here, have been neglected in the present study. Interstratified material is present but always seems to be minor in its diffraction effects. The clay species listed above give sharp intense diffraction maxima (except for kaolinite). Vermiculite is obscured also by chlorite, but the heating experiments are consistent with an interpretation of the major expandable type as a smectite mineral. We have therefore assumed for the estimation of amounts that most samples are smectite, chlorite, and mica, sometimes with kaolinite. The estimation of the amounts of each of these types is done by the following procedure:

1) The diffractometer scans on glycolated samples, 2° 2θ per minute, 0.1° detector slit, Cu K-alpha radiation are used,
2) Peak intensities are measured and background subtracted from this. For smectite the line at 17A is used, for chlorite the line at 7A is used, for mica the line at 10A is used, and for kaolinite the line at 2.4A is used.
3) An estimation of the different relative intensities of the lines listed above were made from examining standard samples of illite, kaolinite smectite, and chlorite.
4) The equations used to derive the amounts of each component make use of the factors alluded to in (3) and are designed so that the sum of all clay components will equal 100 - sum of percentages of primary minerals (Calcite+dolomite+feldspars+quartz).

These equations and the factors used are:

$$s[1.5(I_{chl}) + (1.0\ I_{illite}) + 0.5\ (I_{smectite}) + 10\ (I_{kaolinite})] = 100 - \text{sum of primary mineral percentages}$$

$$\begin{aligned}\%\ \text{Chlorite} &= s \times 1.5 \times I_{chl}\\ \%\ \text{Illite} &= s \times 1.0 \times I_{illite}\\ \%\ \text{Smectite} &= s \times 0.5 \times I_{smectite}\\ \%\ \text{Kaolinite} &= s \times 10 \times I_{kaolinite}\end{aligned}$$

s is a scale factor which scales the sum of the modified intensities to the residual percentage. No real claim to high accuracy for the percentage of individual clay types can be made on the basis of the above procedure. The validity of the absolute percentages that are reported (Table 2) depends on the validity of the scaling factors for smectite, chlorite, mica and kaolinite (0.5, 1.5, 1.0, 10) and these are estimates only. They are made on the basis of standard samples, but we have no way of knowing how closely the standards correspond to the actual minerals in the red clay material. But the relative amounts will be of greater validity since the same procedures are followed for all of the samples listed in Table 2, and it appears that the types of minerals in the Red Clay do not vary in all of the samples that we have so far examined. To say it another way, the clay percentages will be internally consistent, but one cannot easily compare these results with those from another clay occurrence in another locality.

With regard to the validity of the percentages reported in Table 2 they can be ranked in order of merit as follows: 1) quartz, 2) calcite and dolomite, 3) orthoclase and plagioclase feldspar, 4) clay minerals.

In future investigations it may be possible to determine potassium contents on a few of the <0.2μ fractions, which contain essentially no potassium feldspar. A good absolute value for clay mica can be obtained from this and this will aid in deriving more accurate scaling factors.

Or further, a complete chemical analysis with a subsequent allocation of the elements present will provide better estimates of the amounts of chlorite-smectite-mica and so provide a better tie on the sizes of the scaling factors to be used.

RESULTS

Variation in the Red Clay Material

Clay Contents: The data of Table 2 is a summary of size distributions and mineralogies for the samples selected. If the sandy samples at Pearson Creek and at the bottom of the Little Balsam drill hole are excluded the <2μ clay content averages 64.4%. The standard deviation within this group of samples is 11.5% so that most samples will be within about 10% of the mean. Note however that there seem to be regional and stratigraphic differences. The group of samples from the Lakeshore excluding Pearson Creek are higher in clay content (around 70%) than the mean. The samples at the Little Balsam site are lower than the mean (around 50%) down to a depth of approximately thirty-seven feet. Below this depth they are near to or higher than the mean. Some real variation is probably present and further work is needed to map out on a regional basis what these variations are and whether they correlate with regional slope stability observations.

Fine to Coarse Clay Ratios: Although the total amounts of clay may vary widely from the sandy samples such as those at Pearson Creek to the clay rich types such as the Middle River sample there is relatively little variation in the ratio of coarse to fine clay (Figure 8). In the lakeshore samples, and this includes the Pearson Creek examples, the ratio, coarse/fine clay, is 1.11 with a standard deviation of only .105. In the Little Balsam Creek samples the ratio is about the same, 0.99, with a somewhat higher standard deviation of 0.29. This indicates that the clay material tends to be internally relatively homogenous from place to place. The clay may be mixed with varying amounts of sand plus silt but it remains its basic character in the samples we have so far examined. This uniformity is further brought out by the mineralogic characteristics as will be discussed in what follows.

Silt and Sand Contents: The total sand plus silt shows of course a complementary relationship to the clay content. One notes however from Figure 9 that the sand contents are a more variable component than the silt. The average silt content for all fifteen samples is 29.5 and the median is 29. Standard deviation is 11.1 about the same for the clay but is a larger proportion of the mean. The average sand content excluding the Pearson Creek samples and the bottom sample at Little Balsam Creek is 4.2%. The standard deviation for this sample group is 2.4. If one compares the silt/sand ratios for all 15 samples the average is 11.19 and the standard deviation of these ratios is 21.8, larger than the mean itself. The large variability is due to the variable sand content which varies more widely than does the silt. Sand ranges in these fifteen samples from 0.5% to 52.8%. The types of minerals present in the sands and silts in all fifteen samples are generally similar, although there are some differences in mineral amounts from place to place. For example the average quartz content in the medium silt (20-5μ) is 43% and the standard deviation is 8.0%. There do seem to be some regional differences here. If we exclude the quartz values for the medium silt in the Little Balsam hole from 20-40' the average quartz value is 46.6% and the standard deviation is 5.9%. The four samples from the 20-40' depth interval at the Little Balsam site have an average quartz content in medium silt of 33% with a standard deviation of 1.2%.

The calcite and dolomite quantities in the silt fractions vary more widely than do the quartz and feldspar amounts. The carbonates occur principally in the silt sizes, although the occurrence of dolomite in the coarse clay certainly emphasizes that the Red Clay material is a mostly unweathered glacial rock flour. Average total carbonate is 10.3% and the standard deviation is 7.5%, a large deviation compared to the value of the mean. Total values as can be seen in Table 2 range from 1% to 25%. The highest carbonate contents are found in the 20-40' interval of the Little Balsam core where silt contents are also unusually high (>40%). This high carbonate in the silt is correlated with low quartz contents.

It may seem at first anomalous that significant carbonate should be present in the Red Clay material since the rocks of the Lake Superior region are predominantly igneous and metamorphic rocks poor in carbonate. However there are abundant carbonates in the area around Hudson's Bay and glacial movement has been such as to transport material from this region.

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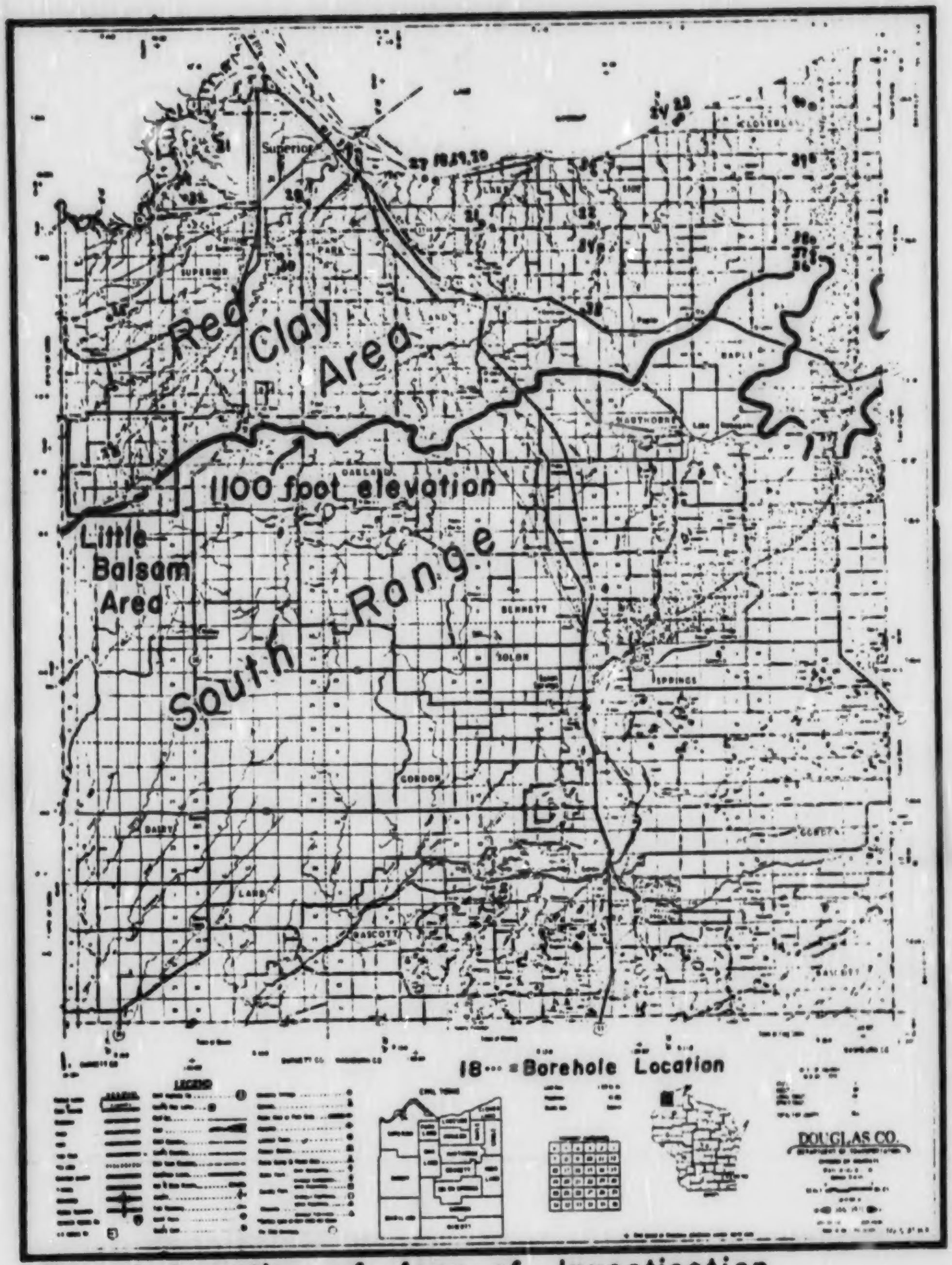

Red Clay Area
Superior
1100 foot elevation
Little Balsam Area
South Range
18··· = Borehole Location
LEGEND
DOUGLAS CO.

Figure 1- Location of Area of Investigation

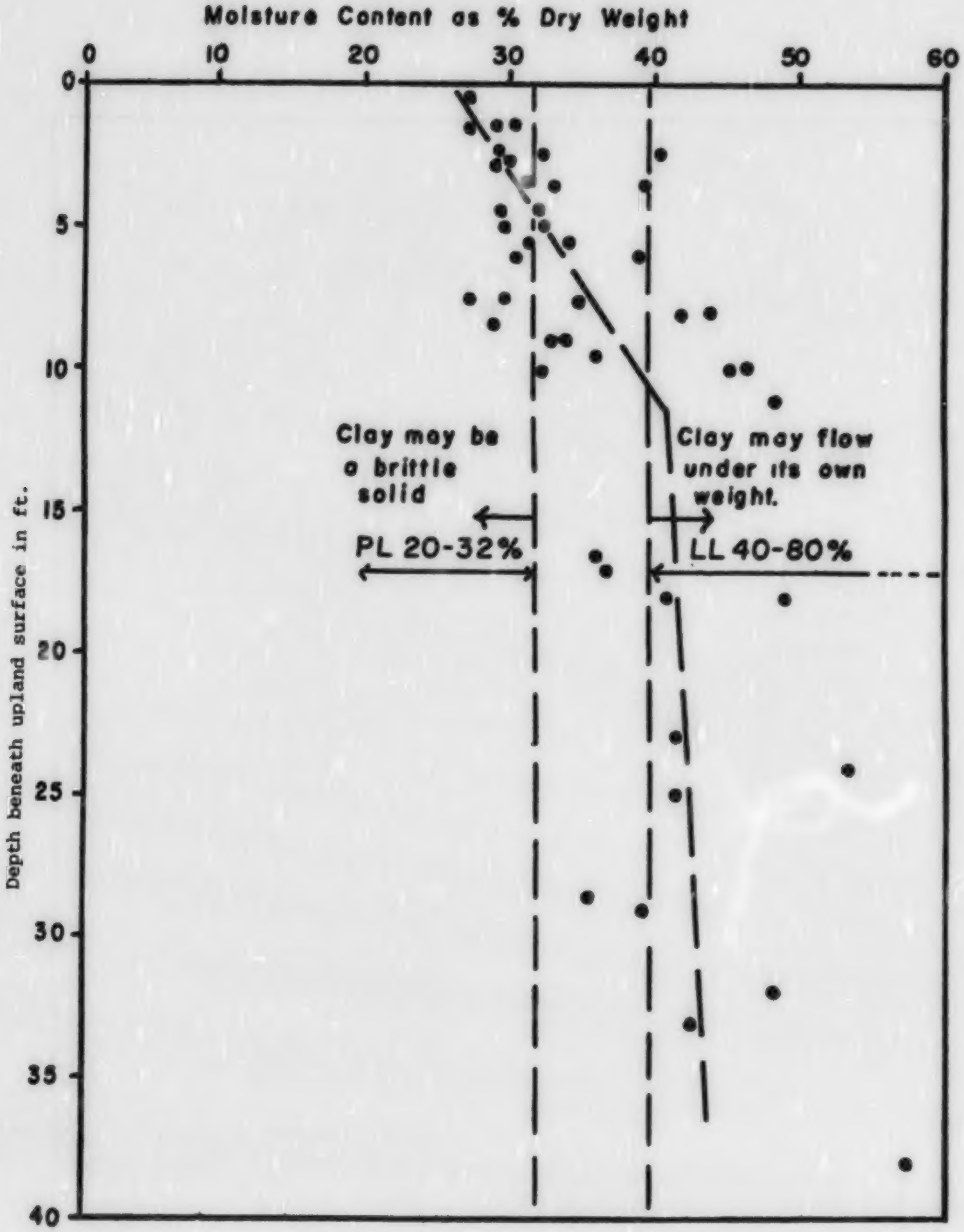


Figure 2 -Clay Moisture/Depth Relationship

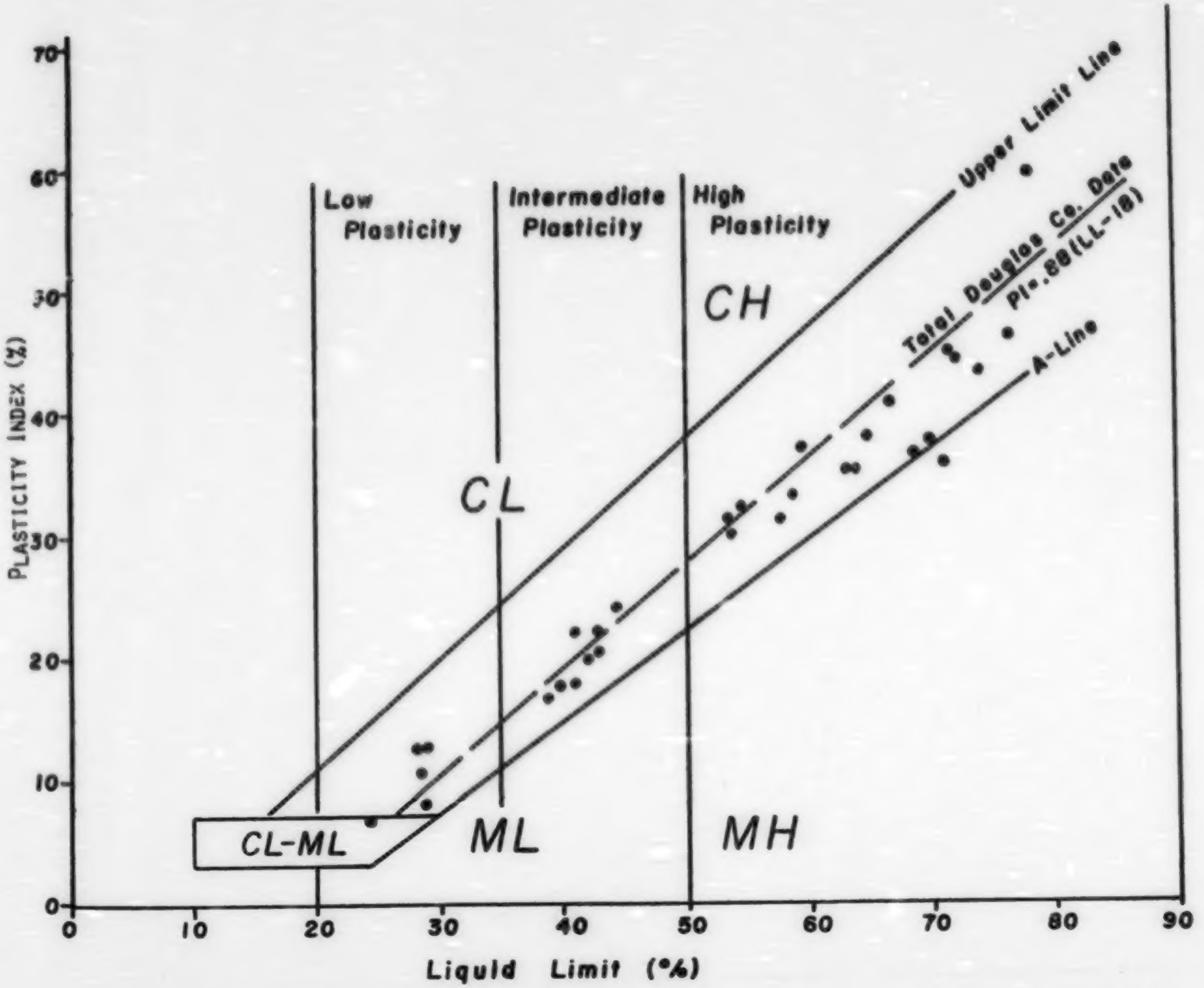


Figure 3.—Unified Soil Classification

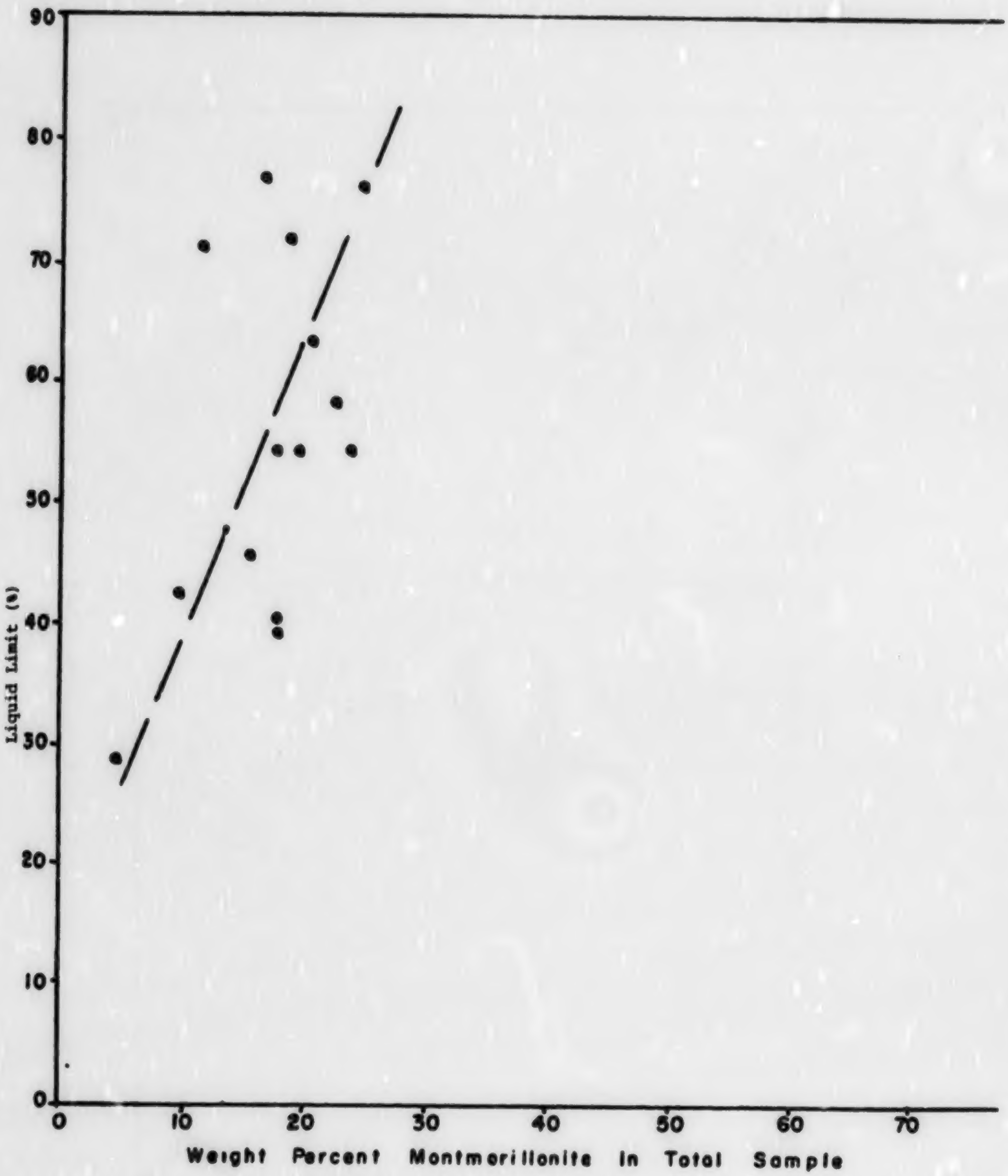


Figure 4 – Montmorillonite in Total Spl. / Liquid Limit

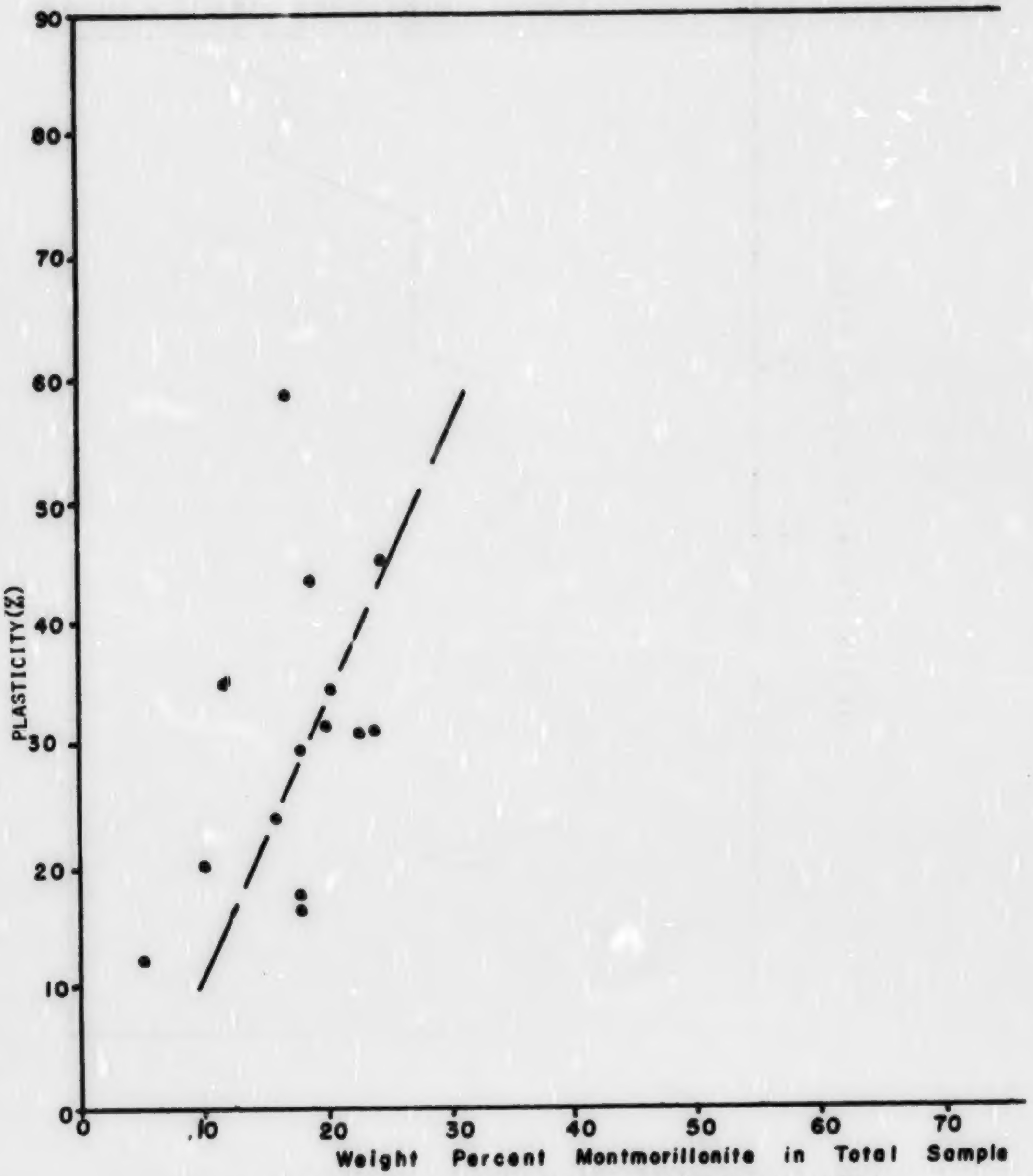


FIGURE 5 -- MONTMORILLONITE IN TOTAL SPL/PLASTICITY INDEX

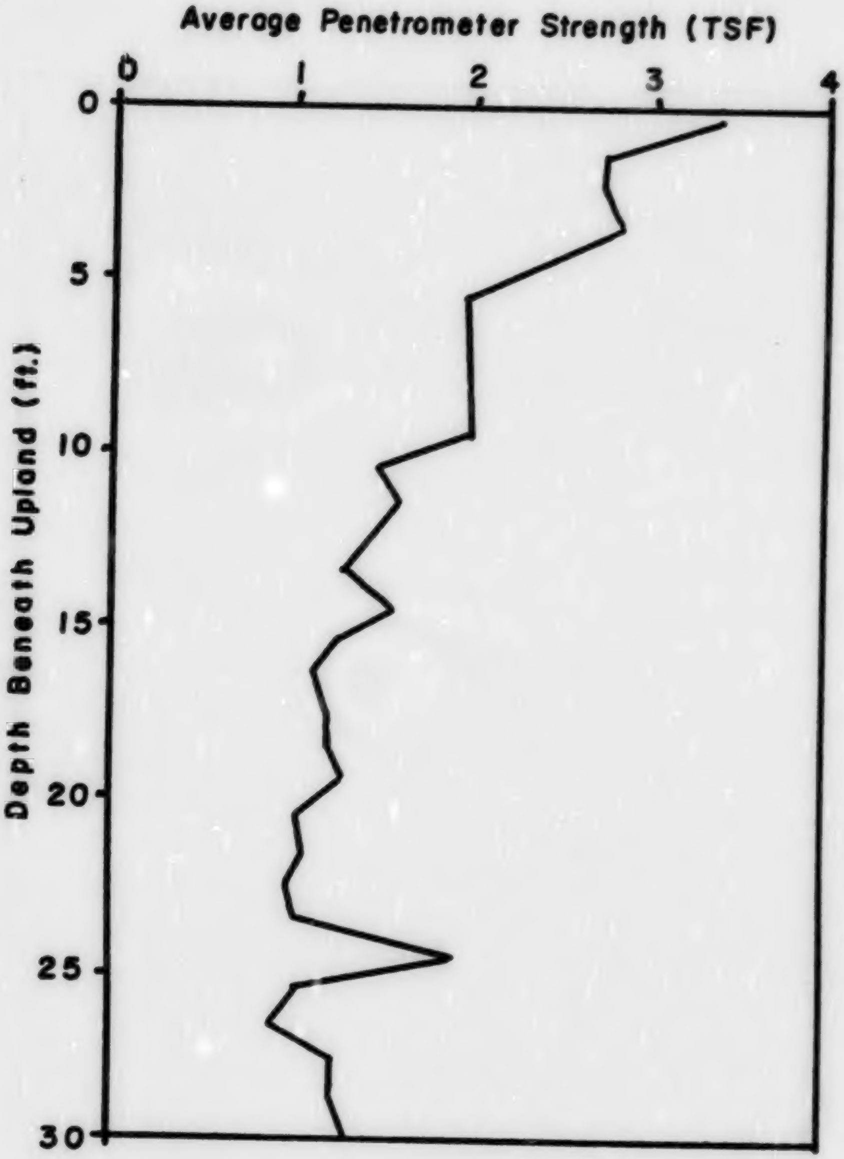


Figure 6 - Strength / Depth Relationship

Average of 9 holes in red clay area

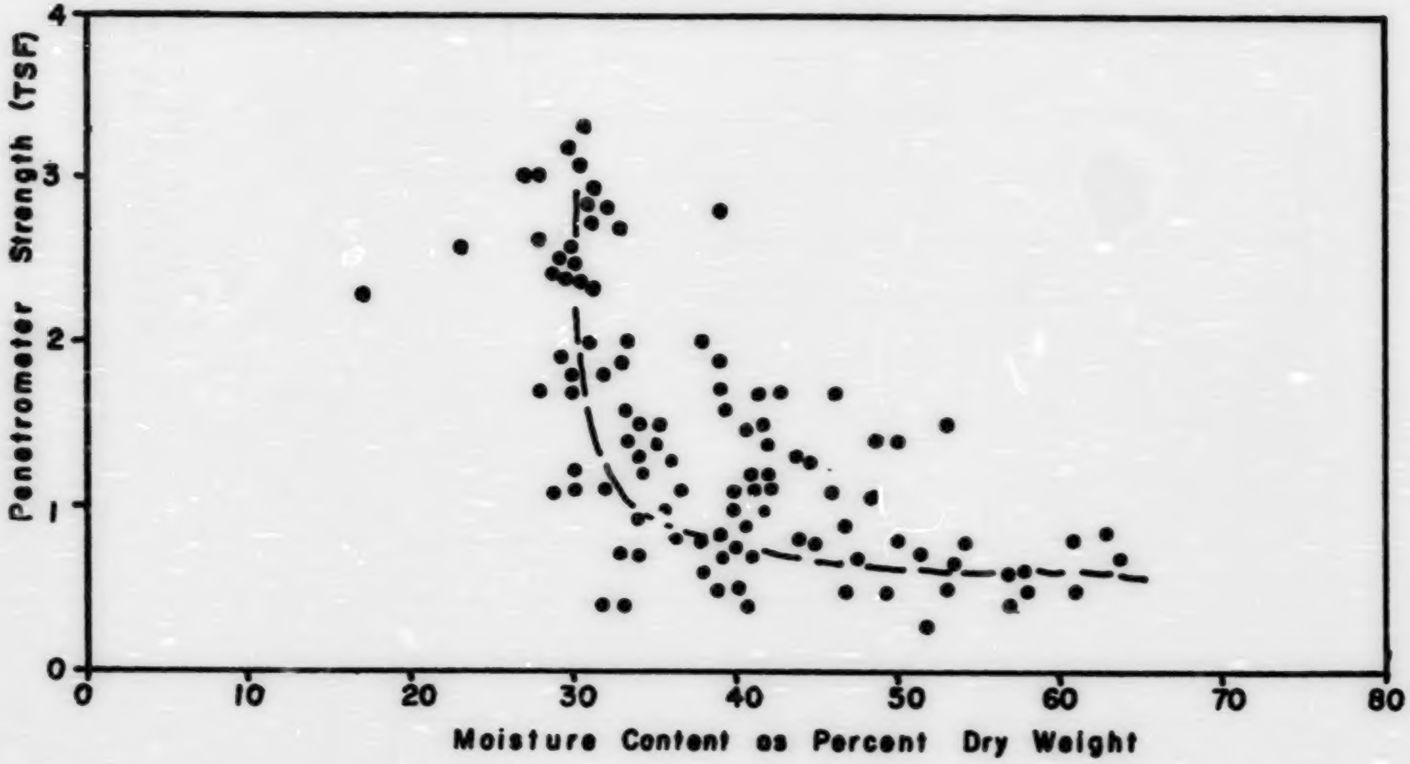
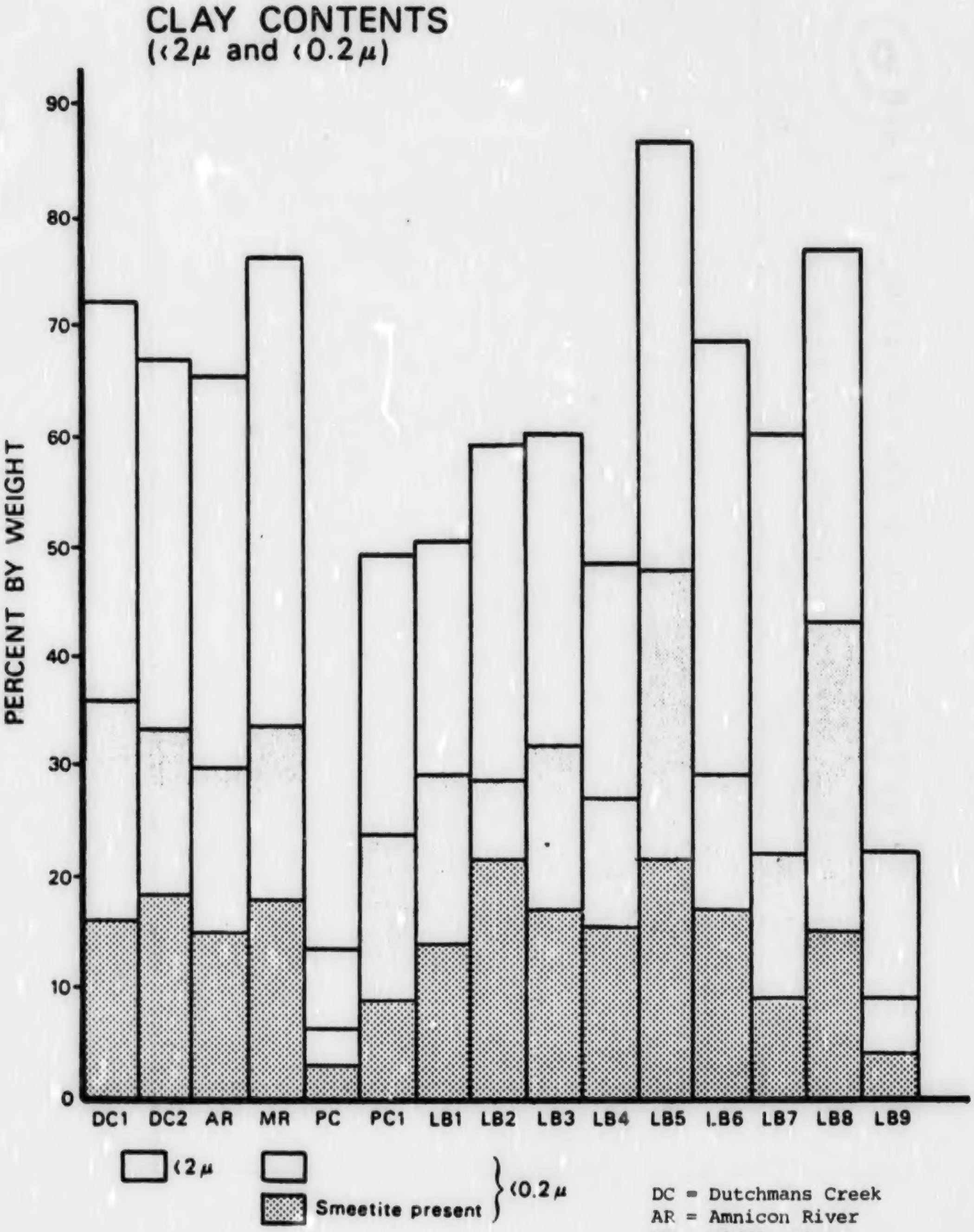


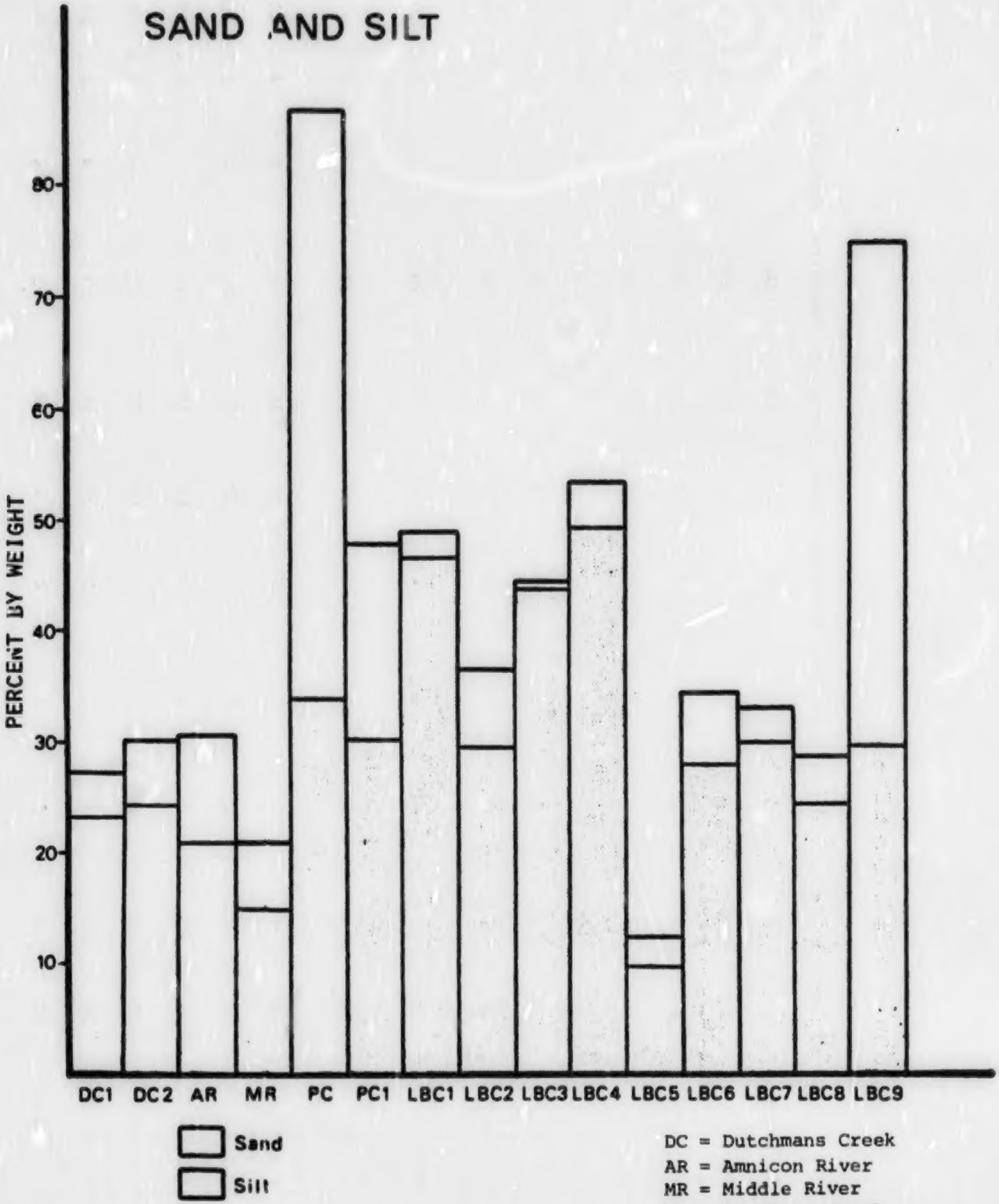
Figure 7 -Penetrometer Strength / Moisture

Figure 8



DC = Dutchmans Creek
AR = Amnicon River
MR = Middle River
PC = Pearsons Creek
LB = Little Balsam

Figure 9



DC = Dutchmans Creek
AR = Amnicon River
MR = Middle River
PC = Pearsons Creek
LB = Little Balsam

TABLE 2

Mineral Content of Whole Sample

Sample	Quartz	Plagio clase	K feldspar	Calcite	Dolomite	Clay Mica	Chlorite	Smectite	Kaolinite	Sand	Silt	Clay
Dutchman's Creek S-1 (4278	18	9	5	7	4	20	24	18	-	3.9	23.2	71.6
Dutchman's Creek S-2	18	8	4	4	5	16	21	23	-	5.7	24.2	66.7
Amnicon River (4281)	22	9	5	4	4	15	19	20	-	9.8	20.7	65.3
Middle River (4282)	16	7	4	7	6	21	23	21	1	6.0	14.9	76.0
Pearson Creek (4283)	60	16	10	-	1	3	4	2	1	52.8	33.9	13.5
Pearson Creek (4284) S-1	32	13	6	6	6	14	15	10	-	17.7	30.1	48.9
Little Balsam Creek (19.5-22') 4236	20	10	3	9	16	11	11	16	5	2.2	46.6	50.3
Little Balsam Creek (24.5-27.0') 4236	15	7	4	6	4	18	19	24	-	7.0	29.4	59.1
Little Balsam Creek (29.5-32.0')	18	7	2	10	14	13	14	18	5	0.5	43.8	60.0
Little Balsam Creek (34.5-37.0')	19	6	2	3	17	10	15	18	5	4.0	49.3	48.3
Little Balsam Creek (39.5-42.0')	14	5	3	5	-	19	31	25	2	2.5	9.8	86.3
Little Balsam Creek (44.5-46.5')	21	10	7	3	2	13	28	19	-	6.4	27.9	68.4
Little Balsam Creek (49.5-51.5')	23	10	4	2	3	13	27	12	-	2.9	30.0	60
Little Balsam Creek (54.5-56.5')	20	10	4	2	2	22	21	17	4	4.1	24.5	76.3
Little Balsam Creek (59.5-61.5')	48	8	8	1	2	9	8	5	4	40.4	34.6	21.9

EFFECTS OF RED CLAY TURBIDITY ON THE AQUATIC ENVIRONMENT

by

W. A. Swenson,* L. T. Brooke and P. W. DeVore**

ABSTRACT

Red clay erosion in the western Lake Superior drainage has reduced the value of the water resource for recreation, navigation and municipal water use. Studies on the effects of turbidity on aquatic life in the lake and the Nemadji River system indicate that fish and benthic invertebrate communities are influenced and exhibit direct behavioral responses to turbidity. Research completed on the lake community shows red clay turbidity results in changes in nutrient levels, quality and depth of light penetration and zooplankton and fish distribution. Changes in distribution alter predator-prey interactions. Major differences in community structure were identified between clear and turbid waters.

Preliminary results from an ongoing study of the effects of erosion and erosion control practices in the Nemadji River system suggest existing turbidity and related clay sedimentation have no significant negative effects on macroinvertebrate standing crops or species diversity. The only major changes in species composition are the addition of burrowing mayflies (e.g. Hexagenia sp., Caenis sp.) when the bottom type is composed primarily of silts and clays. A heavy sand bed-load resulting from erosion and sedimentation results in a generally unstable bottom and extremely low invertebrate production.

No relationship has been identified in the streams between turbidity and fish biomass, but there appears to be a relationship between turbidity and species composition. Clear, cold water tributaries are dominated by Salmonidae in contrast to members of the family Cyprinidae which dominate the turbid, warm water reaches. The fry of rainbow smelt (Osmerus mordax), white suckers (Catastomus commersoni) and longnose suckers (Catastomus catastomus) were found to be numerous in spring drift samples, indicating that high spring turbidity levels in the Nemadji River have little effect on the reproductive success of these species. Although adult game fish were identified in the Nemadji River, no drifting fry were recovered.

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INTRODUCTION

Lake Superior is the largest and one of the purest large bodies of fresh water in the world. Turbidity occurring in the extreme southwestern portion represents the only major exception to this characterization. The turbidity results from erosion of glacial-lacustrine red clay deposits laid down by Glacial Lake Duluth which occur in a continuous zone along 75 km of shoreline from Superior to Port Wing, Wisconsin and cover an area approximating 3,600 km^2 (1). Erosion of clay from shoreline bluffs, river basins and resuspension from the lake bottom is associated with periods of onshore wind, spring runoff and precipitation. Clay plumes may extend from a few hundred meters to several kilometers into the lake.

Employing Earth Resources Technological Satellites (ERTS) images, settling rates and lake and stream sampling, Sydor (2) estimated approximately 2.3×10^6 metric tons of soil is eroded from the Douglas County shoreline. Total erosion from the Wisconsin shoreline was estimated from measurements made by Hess (3), using aerial photographs, at 8×10^6 metric tons annually. Sydor (2) estimated that approximately 1.6×10^6 metric tons of sediment is resuspended from the lake bottom annually in the zone from 0 to 21 meters in depth. He estimates total stream erosion for Douglas and Bayfield Counties approximates 5.9×10^5 metric tons of which 54% or 3.2×10^5 metric tons is carried into Lake Superior. Eighty-nine percent of the stream erosion was contributed by the Nemadji River system.

Influence of erosion related turbidity and sedimentation has been under investigation at the University of Wisconsin-Superior since 1972. Lake studies on water chemistry and fish populations, funded through EPA Grants R-802455 and R-005169-01, and through institutional grants from NOAA to the University of Wisconsin Sea Grant Program, have been completed or are in the final reporting stages. Investigations of the effects of erosion and erosion control on aquatic life in the Nemadji River system are in the data collection and preliminary analysis phases. The stream studies represent one part of the Western Lake Superior Basin Erosion-Sedimentation Control Program reported by Steven Andrews in this symposium.

This report will briefly summarize the knowledge developed from studies on Lake Superior which are published or scheduled for publication elsewhere. Preliminary findings of studies on the Nemadji River system are considered in greater detail. By defining effects of the problem on water quality and the aquatic communities of Lake Superior and the Nemadji River System, the paper should suggest any benefits or costs of erosion control to these communities. Usefulness of data obtained from studies on these systems in defining effects on other lake or stream systems influenced by similar non-point source pollution can also be inferred.

INFLUENCE OF TURBIDITY ON WESTERN LAKE SUPERIOR

Physical-Chemical Effects

Although extensive field sampling demonstrates red clay turbidity seldom exceeds 50 FTU (29 ppm) outside the wave-wash zone (4, 5), Balcer and Swenson (6) showed concentrations as low as 4 FTU (2 ppm) significantly reduced light penetration. The study showed that 17% of incident light penetrated to 4 m in clear water (<0.5 ppm turbidity) in contrast to 0.4% incident light at 6 FTU (3 ppm) red clay turbidity. Turbidity selectively adsorbed energy at the blue end of the spectrum which is the light most significant to photosynthesis.

Bahnick (7) used estimated erosion rates, suspension time and laboratory estimates of chemical exchanges between Lake Superior water and red clay to define contributions of nutrients, heavy metals and minerals to Lake Superior resulting from red clay erosion. His estimates suggest approximately 240 metric tons of orthophosphates are contributed to the lake waters as a result of shoreline erosion. An additional 62 metric tons are contributed from stream erosion. Red clay contributes 207,000 metric tons of dissolved solids, 197,000 metric tons of alkalinity, 14,400 metric tons of silica, 3,500 metric tons of potassium and smaller quantities of various metals including iron (64 metric tons), aluminum (76 metric tons), zinc (<8 metric tons) and copper (3 metric tons) (5). Most of the contributions resulted from shoreline rather than stream eroded sediments. Estimated phosphate loading resulting from red clay erosion appeared small when compared with estimated annual inputs from municipal sewers, industry and harbor activities of 8,130 metric tons (8). However, extensive progress is being made to reduce loading from the point sources resulting in higher significance of the contribution of non-point source red clay erosion.

Effects on Aquatic Life

Comparison of zooplankton densities from clear water Northshore and Apostle Island stations with estimates from areas characterized by periodic red clay turbidity suggested turbidity may increase biological production (6). Zooplankton densities were higher in turbid water and concentrated near the surface. Greater zooplankton densities may reflect higher production of phytoplankton resulting from nutrient and silica enrichment of water at these sites. Swenson and Matson (9) showed larvae of lake herring (Coregonus artedii) distributed closer to the surface of test chambers at turbidity levels characteristic of southwestern Lake Superior. Turbidity levels covering the range normally encountered in the zone did not influence survival or growth of lake herring fry 3-62 days after hatching, the life stage considered to be the most sensitive.

Swenson and Matson (9) suggest red clay may have had a positive effect on larval herring survival and stock size by acting to concentrate larval herring and zooplankton, their food, in Lake Superior near surface waters. This hypothesis is supported by the traditionally high abundance and commercial catches of lake herring from the zone influenced by erosion. Wisconsin waters produced large catches of lake herring until the early 1960's when the population underwent a major decline. Anderson and Smith (10) showed lake herring decline was associated with increased abundance of smelt (Osmerus mordax). Recent studies suggest smelt respond to turbidity by migrating toward the surface. Location away from the bottom resulted in increased percentages of zooplankton and larval fish in smelt diets (4). These studies showed that although turbidity appears to result in greater herring survival in the absence of smelt, turbidity indirectly caused lower survival of larval herring and population decline through its influence on smelt distribution and food habits.

Distribution of walleye (Stizostedion vitreum vitreum) in western Lake Superior and in laboratory turbidity gradients was positively related to turbidity level whereas lake trout (Salvelinus namaycush) avoided turbid water (4).

NEMADJI BASIN STUDY AREA

General Characteristics

The Nemadji River Basin includes 740 km^2 (460 mi^2) in Carlton and Pine Counties, Minnesota and Douglas County, Wisconsin. The basin is essentially a level plain representing a portion of the abandoned lake bed of glacial Lake Duluth. Lake deposits of clay, silt and sand comprise the central portion of the Nemadji watershed. The Nemadji is a young river meandering through a level plain of highly erodable lake sediments. Land use is 90% second growth forest. The area was clearcut in the early 1900's and is now predominantly regrowth of aspen, birch and some pine (11).

Two tributaries to the Nemadji River were selected for implementation of erosion control measures. These are the Skunk Creek Basin in Minnesota, a relatively high sediment-producing watershed covering 17.2 km^2 (10.7 mi^2), and Little Balsam Creek in Wisconsin, a moderate sediment-producing basin covering 9.7 km^2 (6 mi^2). Skunk Creek remains relatively turbid year-round. Stream discharge varied from 0.002-1.25 cms (0.06-44 cfs) in April-mid August, 1976. The average gradient is 6.25 m km^{-1} (33 ft mi^{-1}). Little Balsam Creek is a relatively clear trout stream which maintains a more stable discharge [above 0.025 cms (0.88 cfs) in April-August, 1976]. Average gradient is 20 m km^{-1} (105 ft mi^{-1}). Land use within both watersheds is of relatively low intensity. The primary sediment producing problems are stream bank and roadside erosion.

Study Sites

Sampling sites in the basin were selected to represent the turbidity and sediment types which typify the Nemadji River and tributaries, and to provide information on the immediate effect of erosion control on the aquatic community. Thirteen sites were selected on the Nemadji River, Balsam, Little Balsam, Empire, Skunk and Elim Creeks (Figure 1). Sites were selected as follows:

Site 1: The Nemadji River 0.8 km (0.5 mi) upstream from its mouth where channel is broad (46 m), deep (2.5 m) and of uniform shape. There is no definable gradient and current and direction of water flow over the sand substrate is related to Lake Superior seiches.

Site 2: The Nemadji River approximately 8 km (5 mi) above the mouth. The river is narrower (22 m), deep (2.5 m average) and slow-moving. Currents and water levels are influenced by Lake Superior seiches. The stream bed is bordered by clay banks resulting in some

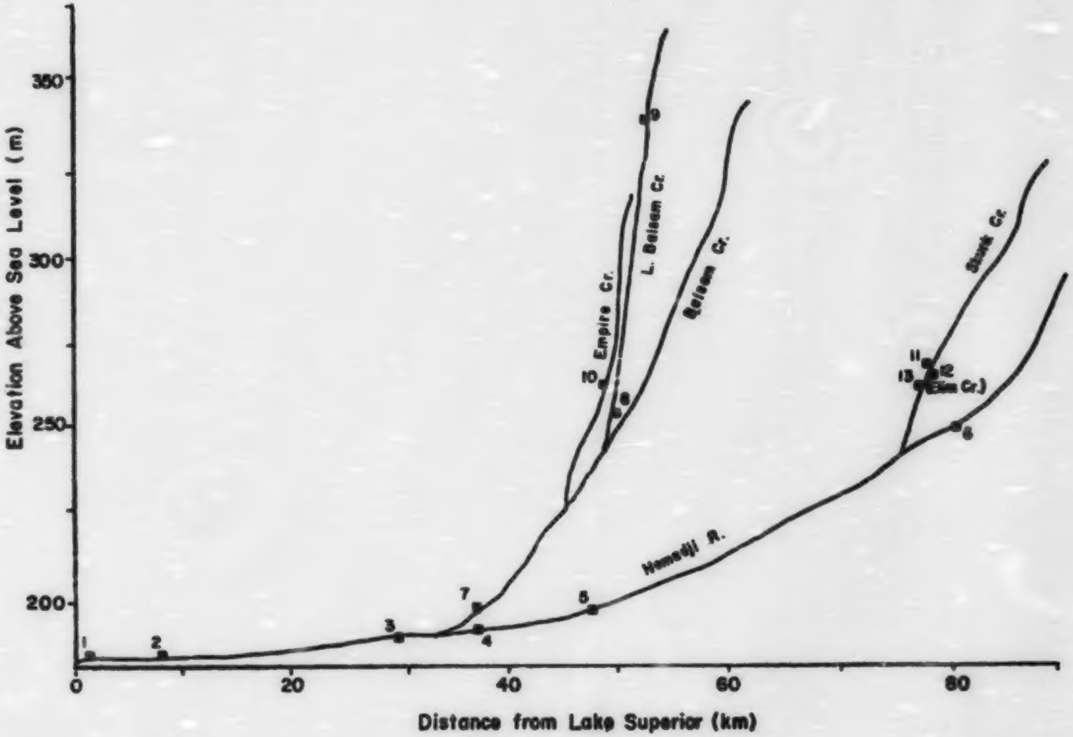

Figure 1. Gradient Map of the Nemadji River and Tributaries With Sampling Stations.

erosion, and the substrate is composed of clay, sand and some gravel.

Site 3: Approximately 30 km (18 mi) above the mouth where the river is shallow (<1 m) with a gradient 0.66 m km^{-1} (3,5 ft mi^{-1}). Erosion of the banks in this region result in a predominantly unstable sand substrate.

Site 4: Nemadji River 35 km (22 mi) above the mouth is physically similar to Site 3.

Site 5: Nemadji River 47 km (29 mi) above the mouth where the character changes to a pool-riffle pattern with rubble and gravel more prevalent in the stream bed. Soils in this location are predominantly silts and clays reducing the sand bedload. The gradient is approximately 1.7 m km^{-1} (9 ft mi^{-1}).

Site 6: North Branch of the Nemadji River 80 km (50 mi) from the mouth where the river has a typical pool-riffle configuration with rubble and boulders prevalent in the substrate.

Site 7: Balsam Creek is classified as trout water by the Wisconsin DNR, but the reaches sampled are turbid throughout the year. The substrate has large quantities of rubble with heavy silt in the pools.

Site 8: Little Balsam Creek below proposed erosion control sites where the substrate is gravel and rubble in riffles and sand in pools. There is some clay sediment but the stream remains clear aside from spring floods. The gradient is 20 m km^{-1} (105 ft mi^{-1}).

Site 9: Upper reaches of Little Balsam Creek well above the area planned for bank stabilization. Rubble and sand make up the substrate. Discharge is lower than in the previous station.

Site 10: Empire Creek which occupies an adjacent drainage basin to the Little Balsam with stream length, watershed size, water quality and substrate very similar to the Little Balsam. This undisturbed watershed was selected to allow more meaningful interpretations of changes in Little Balsam Creek associated with erosion control.

Site 11: Skunk Creek above the influx of Elim Creek where a flood water retaining structure is being constructed and above most of the bank stabilization and channelization planned for Skunk Creek. The substrate is about 35% rubble with silt and clay in the pools.

Site 12: Mouth of Elim Creek which is an intermittent stream that is monitored when a stream flow exists to assess the effects of the proposed sediment retaining structure. The substrate is largely rubble and gravel.

Site 13: Skunk Creek below the proposed construction area, an area physically similar to Site 11, although there is more silt and clay and less rubble. The gradient is about 6 m km^{-1} (33 ft mi^{-1}).

METHODS

Chemical and Physical Characteristics

Estimates of average stream width and depth were made at each sampling site. Qualitative estimates of stream bank erosion, vegetative cover and water color were made at all sampling sites. The substrate of the streams was classified by visual appraisal according to the soil particle size classification described in "Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents" (12).

Dissolved oxygen, conductivity, turbidity and temperature were measured each time a sampling site was visited. In addition, nitrite-nitrogen, nitrate-nitrogen, dissolved orthophosphates and total phosphates were measured every 2-3 weeks beginning August 3, 1976 in Skunk, Elim, Little Balsam and Empire Creeks. Water temperature was measured with a thermister temperature probe. Turbidity was measured in Formazin Turbidity Units (FTU) with a Ecologic Model 102 Turbidimeter. Measurements were converted to parts per million (ppm) using the relationship defined in Figure 2. Dissolved oxygen (DO) was measured with a Yellow Springs Instrument Model 54 DO meter, conductivity with a Yellow Springs Instrument Model 33 conductivity meter, nitrite and nitrate-nitrogen by the cadmium reduction method (13), orthophosphate-phosphorus by the stannous chloride method (13) and total phosphorus by the persulfate digestion method (13).

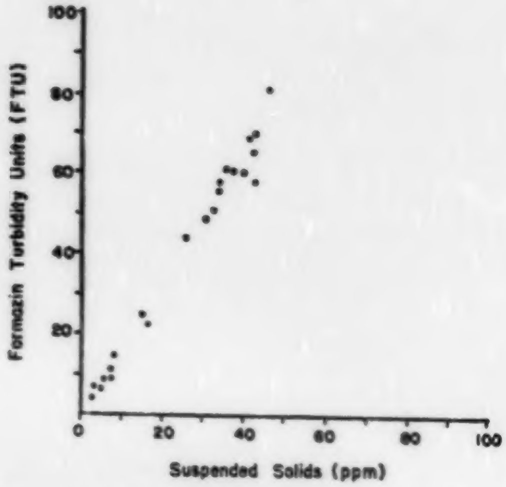

Figure 2. Relationship of Formazin Turbidity Units (FTU) to Suspended Solids in Lake Superior Water.

Macroinvertebrates

Macroinvertebrates were collected at all selected sampling sites in the Nemadji River, Empire, Balsam, Little Balsam and Skunk Creeks. Six benthic samples, generally three in pools and three in riffles, were taken in three sampling periods during the Autumn of 1975. A Surber sampler (0.093 m^2) was used except at Site 1 where water depth necessitated the use of a Ponar dredge. Hester-Dendy type artificial substrate samplers (0.110 m^2 surface) were used at all stations to collect macroinvertebrates. Two pairs of samplers were used at each station (one pair in a pool, the other in a riffle where possible). Samplers were collected after allowing six weeks for colonization by careful removal over a sieve to prevent loss of insects.

All samples were preserved in the field and returned to the laboratory for sorting. Insects were separated by washing through a U. S. Standard No. 35 sieve (32 meshes 2.54 cm^{-1}) and hand picked. Identified to genus was made using keys by Hilsenhoff, Usinger and Pennak (14, 15, 16).

Fish Population Assessments

Fish populations were sampled monthly (May-November) at all sites during Autumn 1975 and at nine sampling sites during 1976. Sites 1 and 2 were sampled with trapnets (0.9 x 1.8 m pot, 15.2 x 0.9 m lead of 2.54 cm bar mesh) in 1975. Two nets were set at each site and fish were removed every twenty-four hours, identified, measured and weighed. Site 1 was sampled in 1976 only during May and June. Trapnets were used because water depth exceeded that at which available electrofishing gear is efficient.

The remaining sites were electrofished with either a 300 watt or a 1250 watt DC current portable generator, a 1000 watt DC current stream shocker with variable voltage and pulse rate or two 350 watt backpack AC-DC current shockers. The unit used was dependent upon water depth and volume.

Sampling sites in the four tributary creeks were premeasured in three 61 m lengths. One length was fished each month. Longer stretches were sampled in the Nemadji River with the length of the three premeasured sections equal to ten times the average stream width. The lengths chosen were long enough to include both pools and riffles where they occurred. Fish captured with the electrofishing units were identified, weighed, measured and returned to the stream at the completion of fishing a section. Representative scale samples were collected from major species populations.

Spawning success in the Nemadji River was estimated from samples of larval fish collected by two drift nets (30.5 x 14.0 cm with 571μ mesh) placed in the river near the Douglas County Highway C bridge. The nets were placed in the water at the surface and 0.5 m beneath the surface daily for 15 min. Sampling began on 8 May and continued until no larval fish were captured. Current velocity was measured at the mouth of each net using a Pygmy Gurley current meter to determine the volume of sampled water. Larval fish captured were preserved for later identification and counting in the laboratory. Larvae were identified using the taxonomic keys of Fish and Norden (17, 18).

Egg Survival Studies

A constant flow, temperature and turbidity controlled apparatus was constructed for incubating fish eggs. The apparatus was essentially a gravity flow system utilizing dechlorinated City of Superior water. Temperature modifications were made in a common water reservoir. One half of the water supply was increased in turbidity to 50 FTU using equipment described by Swenson and Matson (9) and clay from Site 8. The other half remained clear (1 FTU). Proportionate mixing of the turbid water with the clear water resulted in the intermediate turbidity values of 10 and 25 FTU. Mean turbidity values for the four treatments for the 14 day duration of the study were 1.3, 9.2, 23.2 and 48.5 FTU. Water temperatures were maintained near 10 C. Mean temperatures were 9.9, 10.0, 10.0 and 10.1 C for the respective nominal turbidities of 1, 10, 25 and 50 FTU. The systematic increase in water temperature with turbidity was due to recycling of half the water over the clay source to increase turbidity.

The incubation chambers were constructed to simulate stream substrate and current conditions. Four channels were used for each turbidity level with each channel subdivided into four chambers by 530μ mesh opening stainless steel screen. This allowed for two replicate samples of eggs for two fish species per channel. Each channel was 19.0 cm long, 3.0 cm wide and 2.5 cm deep. Two of the channels were filled to a depth of 2.0 cm with washed sand (≤0.7 mm) and the other two were filled to the same depth with gravel (<20 mm but ≥10 mm). Each of these paired substrates differed in current velocity by a factor of approximately two.

Eggs of rainbow smelt were obtained from adults taken in Allouez Bay of the Duluth-Superior Harbor on April 29, 1976. The adults were transported alive to the laboratory at the bay water temperature (10.6 C). Eggs from 5 females were fertilized with sperm from 8 males and hardened for 30 minutes in petri dishes at 10.0 C. Random samples were then withdrawn and placed in the incubation chambers. Egg counts were made at the completion of the incubation period (14th day). Numbers of eggs per incubation chamber ranged from 134 to 749 with a mean of 374.9. At the onset of first hatch the remaining eggs were sorted from the sand and gravel, identified as alive or dead (dead eggs were opaque) and counted.

RESULTS

Chemical and Physical Characteristics of Sampling Sites

Water temperature generally increase in the Nemadji River system from its headwaters to the mouth with the exception of Site 1 which was influenced by Lake Superior seiches. The highest temperature recorded was 26.7 C at sampling site 5 on 14 July 1976. Temperatures were higher in the turbid water tributaries than clear tributaries (Table 1).

Dissolved oxygen under normal conditions, ranged from 54 to 119% of saturation during the ice-free sampling season. There was no relationship between turbidity and DO levels. The low value was measured at sampling Site 1 on 29 April 1975 and the high at sampling Site 5 on 11 September 1975. A point source pollution problem decreased the dissolved oxygen to <5% of saturation at sampling Site 1 during June and July 1976.

Table 1. Distance from Lake Superior, Substrate Composition, Mean Stream Width, Mean Stream Depth, Mean Annual Water Temperature and Mean Annual Turbidity of Nine Sampling Sites in the Nemadji River System.

	Nemadji River			Empire Creek	Little Balsam Creek		Elim Creek	Skunk Creek	
Sampling Site Number	1	4	5	10	8	9	12	13	11
Kilometers From Lake Superior	0.8	36.2	46.7	48.4	49.9	52.3	78.2	77.2	78.9
Substrate Composition	Clay	Sand	Sand	Sand	Gravel	Rubble	Gravel	Clay	Gravel
Mean Stream Width (m)	39.6	15.2	18.6	1.8	3.7	1.5	1.8	6.7	2.4
Mean Stream Depth (m)	2.6	0.3	0.6	0.2	0.2	0.2	0.1	0.7	0.5
Mean Annual Water Temp. (C)[a]	14.6	12.5	13.9	9.5	10.6	9.9	11.4	10.9	10.7
Mean Annual Turbidity (FTU)[a]	34.1	33.4	32.6	6.6	8.9	4.8	42.6	49.8	38.8

[a] Values based upon data from ice-free months.

Conductivity reached maximum values during late summer and decreased until the occurrence of ice cover. Dilution by snow melt runoff in the spring further decreased the conductivity of the water. The range of values measured in the Nemadji River system was 30 to 280 μmhos cm^{-1}. Conductivity values were lowest in the clear tributaries and increased downstream to sampling Site 4. Lake seiches often diluted the river water at sampling Site 1 and reduced conductivity.

Turbidity in the Nemadji River was quite uniform between sampling sites and relatively low during late summer and autumn. Heavy rains just before freeze-up in 1975 and snow melt runoff during the Spring 1976 increased the turbidity to its maximum values. The range of measured values for all sampling sites was from 1 to 260 FTU. The lowest values were measured in Empire and Little Balsam Creeks and the highest in Skunk Creek (Table 1).

Measurement of major nutrients (nitrogen and phosphorus) was begun in August of 1976 in four of the Nemadji River tributaries. Lack of rain and related low runoff and low stream flows have resulted in low values at all sampling sites. Nitrite-nitrogen was nearly nonexistent in all streams (Table 2). The maximum value was 43.9 ppb in Skunk Creek. However, nitrate-nitrogen was measured in higher concentrations and ranged from 0 to 671 ppb. Empire and Little Balsam Creeks, characterized by the lowest turbidity, had the highest values. The maximum soluble orthophosphate level was 39 ppb. Orthophosphate was below detectable levels in the low turbidity tributaries. Total phosphorus values were higher in the low turbidity tributaries (Table 2).

Table 2. Range and Mean (In Parenthesis) of Values for Nitrite-N, Nitrate-N, Ortho and Total Phosphorus for Water From Four Tributaries of the Nemadji River From August Through October 1976.

	Skunk Creek	Elim Creek	Little Balsam Creek	Empire Creek
Nitrite-N ppb	0.0-43.9 (14.5)	0.0-0.0 (0.0)	0.0-24.1 (12.1)	0.0-4.2 (2.1)
Nitrate-N ppb	0.0-604.0 (166.5)	0.0-136.7 (63.1)	36.5-671.0 (342.8)	8.9-589.0 (243.5)
Orthophosphate ppb	0.0-39.0 (3.6)	0.0-25.0 (6.2)	0.0-0.0 (0.0)	0.0-0.0 (0.0)
Total Phosphorus ppb	9.7-186.0 (51.0)	0.0-223.0 (68.9)	0.0-525.0 (120.5)	0.0-129.0 (69.5)

Macroinvertebrates

Diversity of macroinvertebrates and total number per 0.092 m^2 (1 ft^2) were defined for benthic samples at all sites. Diversity was calculated using the Shannon Weaver Index (EPA manual) (12). Diversity was not correlated with mean annual turbidity (Figure 3), but increased in

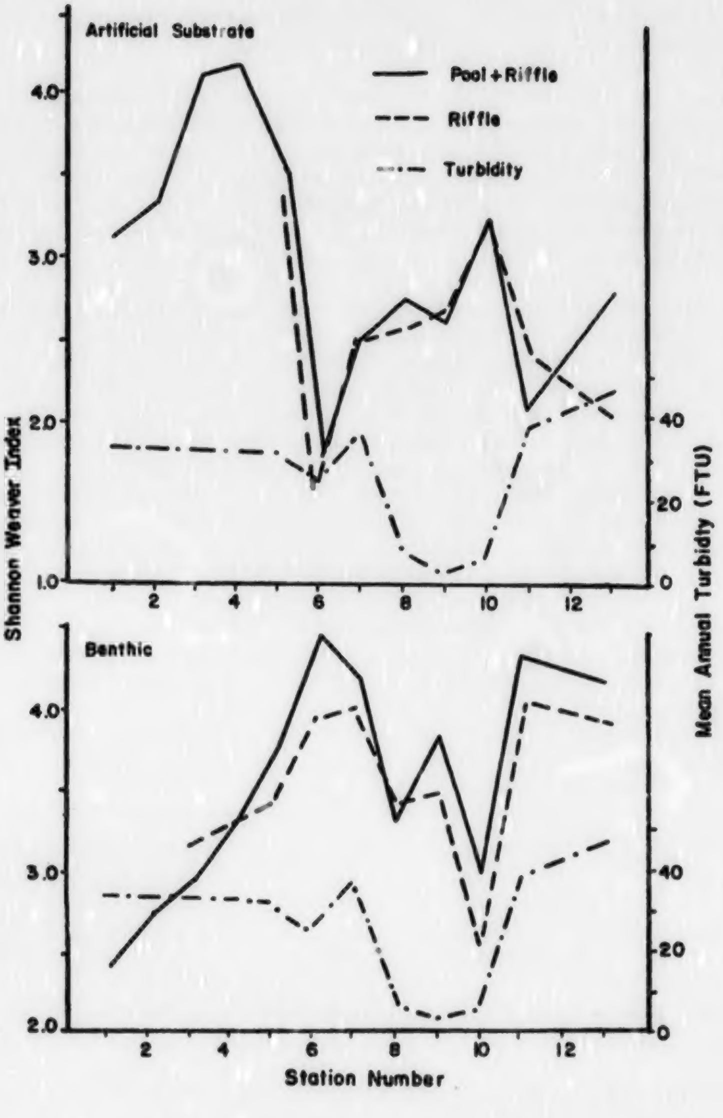

Figure 3. Shannon Weaver Diversity Index for Benthic and Artificial Substrate Samples in Riffles and Pools + Riffles and Mean Annual Turbidity (FTU) in the Nemadji River and Tributaries, Autumn 1975.

the upstream direction in the Nemadji River (Sites 1-6). Clear-water tributaries (Sites 8, 9 and 10) had lower diversity values than the more turbid Skunk Creek (Sites 11 and 13). No benthic samples were collected in Elim Creek (Site 12) which was dry throughout the autumn sampling period.

Trends which appeared in diversity of the benthic samples were not evident for Hester-Dendy samples (Figure 3). Again there was no correlation with mean annual turbidity. Diversity calculated from benthic and artificial substrate samples appeared to be negatively correlated ($r=-0.39$), but the relationship was not significant.

The number of organisms per 0.092 m^2 was calculated independently for erosional (riffle) and depositional (pool) habitats (Figure 4) and showed no correlation with turbidity. Variation in numbers of organisms was most closely associated with changes in substrate being higher in riffles (which did not occur in Sites 1-4) and silted pools than in the unstable sand substrate characterizing Sites 3 and 4.

Number of organisms on the artificial substrate samplers showed no consistent changes with turbidity (Figure 5). The larger number of organisms at Sites 11 and 13 (turbid water) were composed primarily of Chironomidae (midge larvae), which inhabited the heavy silt layers deposited on the samplers.

The most dramatic effect of erosion is in the reaches of the river where large quantities of sand are contributed to the bed-load (Sites 3 and 4). This broad and shallow area lacks a stable substrate preventing the formation of a step-like continuum of riffles and pools. The lowest benthic populations occur in these areas with only the biting midges, Ceratopogonidae, seemingly adapted to the shifting sand. Both pools and riffles occur in all of the more upstream sites where the bed load is not great enough to cover the riffle areas. The pools have a fairly stable substrate of sand in the clear water stations (Sites 8-10) and silts and clays in the turbid sites (11 and 13).

The turbid tributaries support as large a benthic population as do those streams with minimal erosion and high water clarity. The lowest populations, in fact, occur at Site 10 which has one of the lowest mean annual turbidities. This site has low populations in both the erosional and depositional habitats. Small gravel predominates in the riffle areas as opposed to rubble and large gravel at all other sites. The data suggest lack of the larger substrates is a major factor in reducing benthic populations.

The positive effects of a stable substrate and detritus trap can be demonstrated by a comparison of the organisms in the unstable sand substrate of Site 3 with a substrate sample at the same station where detritus was trapped and with the Hester Dendy samples (Table 3). Mid-channel samples presented a severe environment, lacking both food and a stable substrate, resulting in a low number of organisms and genera. The sample with detritus provided abundant food and protection. Insect biomass was high as many of the organisms were the large stonefly, Pteronarcys dorsata. The stable substrate of the Hester-Dendy samples recruited a large number of genera.

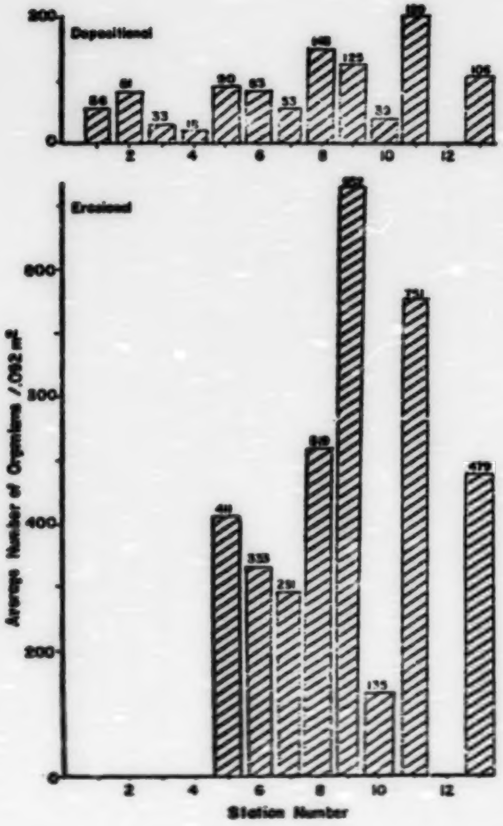

Figure 4. Average Number of Organisms/.092 m^2 (1 ft^2) in Benthic Samples in Erosional and Depositional Habitats in the Nemadji River and Tributaries, Autumn 1975.

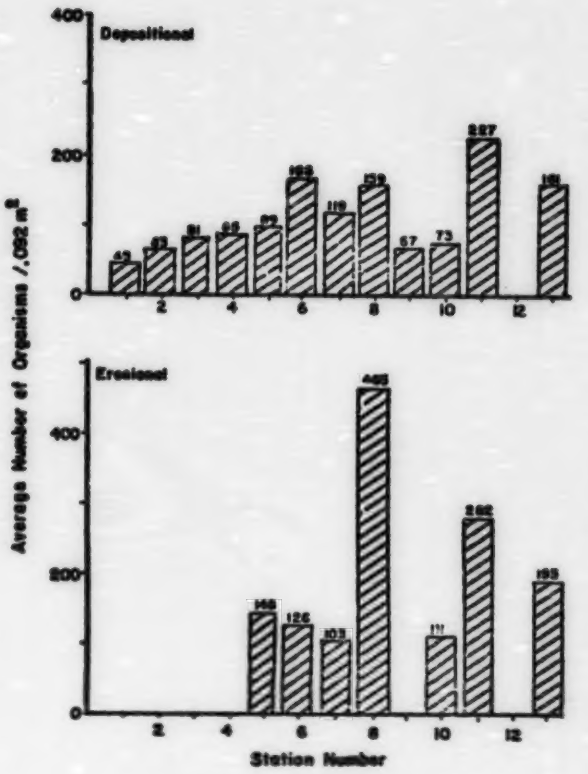

Figure 5. Average Number of Organisms on Artificial Substrate Samplers in Erosional and Depositional Habitats in the Nemadji River and Tributaries, Autumn 1975.

Table 3. Average Number of Organisms and Genera in a Surber Sample in Detritus, Ten Sand Substrate Mid-Channel Surber Samples, and Artificial Substrate Samplers, Autumn 1975.

Sample Type	No. of Genera	No. of Organisms
Detritus	17.0	115.[illegible]
Mid-Channel	4.3	18.[illegible]
Hester-Dendy	26.0	87.5

All genera that appeared at the clear-water stations (Sites 8, 9 and 10) were found in the turbid tributary (Sites 11 and 13). The addition of some genera of mayflies (Hexagenia sp., Ephemera sp, and Caenis sp.) indicate the preference of these burrowing forms for more silt-laden substrates than are found in the sandy pools characteristic of the clear streams.

Consideration of the benthic communities by functional groups illustrate absence of differences attributed to levels of clay turbidity or clay sedimentation encountered thus far in this study. Genera were considered individually as carnivores or herbivores (including grazers, filter feeders and shredders) and the relative numbers were compared between Little Balsam (clear water) and Skunk (turbid water) Creeks. Remarkable similarity existed between the two, with carnivores$(.092\ m^2)^{-1}$, herbivores $(.092\ m^2)^{-1}$, and the herbivore to carnivore ratios nearly identical (Table 4).

Table 4. Average Number of Carnivores and Primary Consumers per .092 m^2 in Little Balsam and Skunk Creeks, Fall 1975.

	Little Balsam Creek		Skunk Creek	
Functional Group	Number of Taxa	Number of Organisms	Number of Taxa	Number of Organisms
Carnivores	13	24.4	16	23.6
Primary Consumers	31	365.9	38	359.2
Primary Consumers/Carnivores	2.38	14.99	2.38	15.22

Distribution and Diversity of Fishes

The combined catch from nine sampling sites from August 1975 through October 1976 was 12,487 fish representing 37 species (Table 5). Catastomidae and Cyprinidae increased in abundance from the river mouth to headwaters of the turbid tributaries (Table 6). Salmonidae dominated the fish populations in the clear tributaries but were conspicuously absent elsewhere.

Table 5. Species of Fish Captured in the Nemadji River and Four Tributaries From August 1975 Through October 1976.

Brook Trout	*Salvelinus fontinalis*
Brown Trout	*Salmo trutta*
Rainbow Trout	*Salmo gairdneri*
Northern Pike	*Esox lucius*
Muskellunge	*Esox masquinongy*
Walleye	*Stizostedion vitreum vitreum*
Yellow Perch	*Perca flavescens*
Logperch	*Percina caprodes*
Johnny Darter	*Etheostoma nigrum*
Rainbow Smelt	*Osmerus mordax*
Burbot	*Lota lota*
Brook Stickleback	*Culaea inconstans*
Troutperch	*Percopis omiscomaycus*
Mottled Sculpin	*Cottus bairdi*
White Sucker	*Catostomus commersoni*
Longnose Sucker	*Catostomus catastomus*
Silver Redhorse	*Moxostoma anisurum*
Shorthead Redhorse	*Moxostoma macrolepidotum*
Central Mudminnow	*Umbra limi*
Black Bullhead	*Ictalurus melas*
Tadpole Madtom	*Noturus gyrinus*
Stonecat Madtom	*Noturus flavus*
Rock Bass	*Ambloplites rupestris*
Black Crappie	*Pomoxis nigromaculatus*
Carp	*Cyprinus carpio*
Creek Chub	*Semotilus atromaculatus*
Hornyhead Chub	*Nocomis biguttatus*
Lake Chub	*Couesius plumbeus*
Longnose Dace	*Rhinichthys cataractae*
Blacknose Dace	*Rhinichthys atratulus*
Pearl Dace	*Semotilus margarita*
Brassy Minnow	*Hybognathus hankinsoni*
Fathead Minnow	*Pimephales promelas*
Common Shiner	*Notropis cornutus*
Blackchin Shiner	*Notropis heterodon*
Blacknose Shiner	*Notropis heterolepis*
Emerald Shiner	*Notropis atherinoides*

Spring (April and May) samples produced greater numbers and biomass of fish in the Nemadji River sampling sites (1-5) than are encountered during the remainder of the sampling season. This was especially evident at Site 5 which has a gravel substrate. This area appears to be suitable spawning habitat for rainbow smelt, longnose suckers, white suckers, silver redhorse (*Moxostoma anisurum*) and shorthead redhorse (*Moxostoma macrolepidotum*). A single ripe female walleye was also captured.

Table 6. Mean Values of Fish Numbers (# Hectare^{-1}), Biomass (Kg Hectare^{-1}) and Fish From the Nemadji River and Four Tributaries for the 1976 Sampling Season.

Sample Site	Salmonidae		Catastomidae		Cyprinidae		Other		Total Biomass (Kg)	Diversity Index[a]
	#	wt.	#	wt.	#	wt.	#	wt.		
4	0	0	90	1.81	326	2.55	108	0.99	5.4	1.01
5	0	0	162	5.36	256	4.09	288	2.35	11.8	0.97
8	1141	31.44	559	3.79	5073	21.00	5535	12.14	68.4	0.70
9	5249	113.64	58	6.53	0	0	2915	8.98	129.1	0.40
10	10923	169.55	0	0	97	1.16	2623	16.27	187.0	0.32
11	0	0	2077	112.38	9250	106.63	3133	7.50	226.5	0.81
12	0	0	777	11.92	10780	144.54	2913	10.39	166.9	0.68
13	13	5.23	172	2.61	2265	19.57	981	1.99	29.4	0.84

[a] Shannon-Wiener Index

Diversity indices were computed for each sampling site from 1976 collections (Table 6). Numbers and biomass data associated with large lake runs of spawning fish was not included in the analyses to characterize the various sampling sites. Generally diversity increased with stream size and decreased with an increase in Cyprinidae populations. Diversity was lowest in the trout streams (stations 8, 9 and 10) and within the trout streams diversity decreased towards the headwaters where trout abundance increased.

Larval Fish Production

The Nemadji River contains high population densities of larval fish during the month of May. Sampling was begun on 8 May and continued until 23 May when the fry density approached zero. Larval fish drift downstream upon hatching into the Superior-Duluth Harbor and Lake Superior. Rainbow smelt were the first group of larval fish to appear. Smelt were first noted on 10 May, increased in density until 14 May, then declined until 23 May (Figure 6). Distribution of fry was uniform through the water column.

The second group of larval fish captured drifting downstream was composed of suckers (white suckers, longnose suckers, shorthead redhorse and silver redhorse have been found as spawning adults). Sucker fry did not appear in any numbers until 21 May. The fry were almost entirely restricted to the upper 5-10 cm of the water column and stopped drifting on 23 May (Figure 7).

Rainbow Smelt Egg Incubation

Survival of rainbow smelt eggs incubated at different flow velocities, turbidities and on two substrates did not vary as a result of test conditions. The eggs of rainbow smelt hatch in 15 days at 10.0 C (personal communication with J. Howard McCormick, Environmental Research Laboratory, Duluth, Minnesota) which necessitated terminating the study

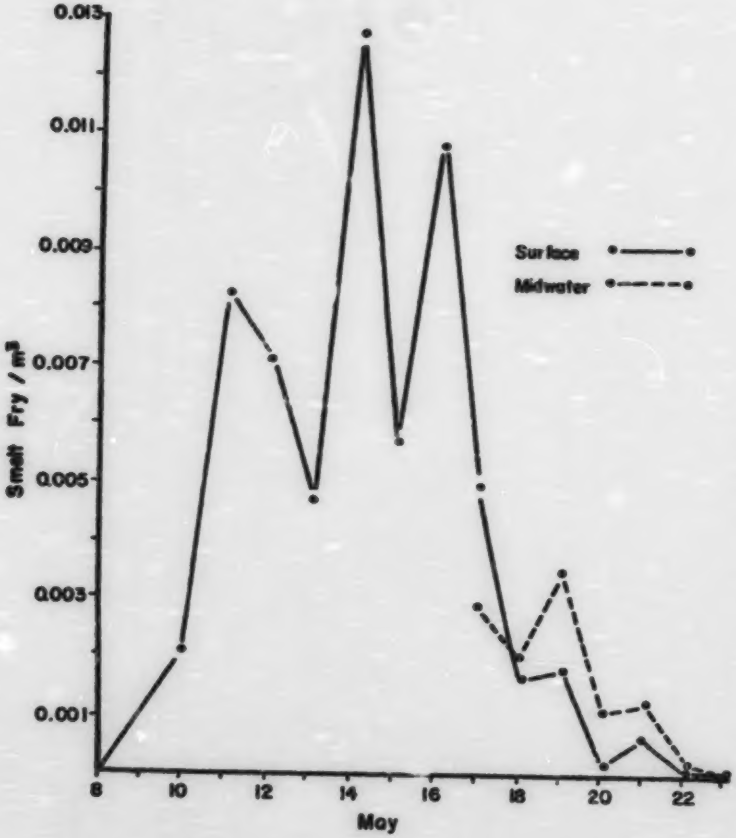

Figure 6. Number of Rainbow Smelt Fry/m^3 Captured at Douglas County Road C on the Nemadji River.

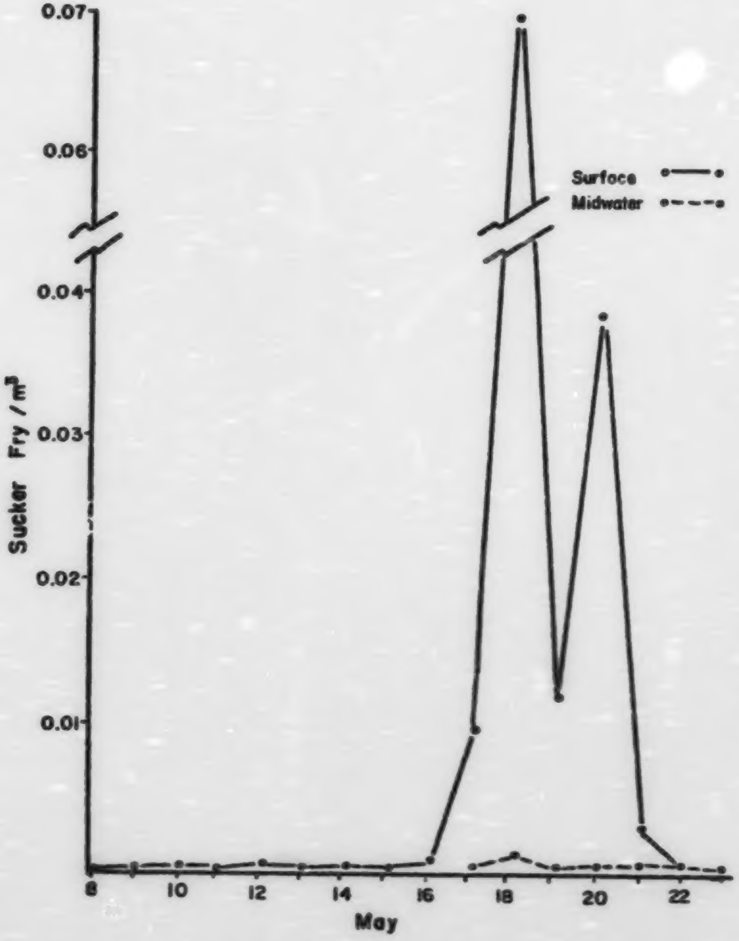

Figure 7. Number of Sucker Fry/m^3 Captured at Douglas County Road C on the Nemadji River.

on the 14th day of incubation due to the ability of fry to pass through the 530μ mesh openings used as barriers between replicate samples. Survival ranged from 30.2 to 74.0% for individual replicates (Table 7) with the mean of paired replicates ranging from 33.1 to 60.4%.

DISCUSSION

The effects of turbidity and sedimentation on aquatic life have generally been studied in situations where there are massive movements of soils (e.g. logging operations, poor agricultural practices over large areas) or a source of inorganic sediments (sand pit washing, clay wastes, etc.). The burden of sediment which is discharged into a stream under these conditions has offered excellent opportunities to assess the effects of extremely high levels of stream sedimentation on aquatic life (19, 20, 21). Few studies, however, have been involved with the effects of erosion and the resultant turbidity and sedimentation which occur naturally in a young river system flowing through highly erodable bed materials as is the situation in the glacial lake deposits characterizing the Nemadji River Basin.

Macroinvertebrates

The effect of heavy sedimentation on stream macroinvertebrates has been shown by some authors to affect numbers and biomass of organisms with very little associated change in species composition (20, 21). Herbert *et al*. (21) found the bottom fauna to be 3.3 times more numerous where heavy clay sediment was not polluting the stream. No changes in species composition were noted. Turbidity levels of the polluted stream varied from 900-7500 ppm, which is a minimum of 10 times the levels found in the Nemadji Basin. Other authors, including studies cited by Cordone and Kelly (22) and Chutter (23), found significant changes in the bottom fauna with increased siltation.

The effect of sedimentation on the benthic fauna seems to be manifested primarily through changes in the character of the stream substrate. Complete inundation of pools and riffles by silt and sand, as has occurred in several studies, would have obvious effects on composition through the formation of a monotypic environment. It is also a very unstable environment, unsuitable for trapping detritus and prone to be flushed away during floods. When the stream substrate is not completely covered, reduction in benthic populations may occur through the elimination of interstitial space. The preference (or greater population size) of insects has been found to be large rubble > medium rubble > gravel > bedrock > sand (24, 25, 26). Generally, the more interstitial space, the higher the preference for the substrate.

Diversity of the benthic samples increased in an upstream direction on the Nemadji River (Sites 1-6), indicative of the gradation of substrates from sand to gravel to rubble. Diversity was slightly higher in the turbid tributaries (Sites 7, 11 and 13) than in the clear streams reflecting the increase in the burrowing or silt-loving forms. The slight negative correlation of diversity indices between the benthic and artificial substrate samples show a distinct substrate selection. Diversity indices for the artificial substrates have the highest and lowest values at Sites 3, 4 6 and 10 (Figure 3). Consideration of the

Table 7. Percentage Survivals of Rainbow Smelt Embryos Incubated at Different Values of Turbidity and Current Velocity on Sand and Gravel. (Values in Parenthesis are the Means of the Replicate Samples.)

Sub-strate	Relative Flow Velocity	Nominal Turbidity Values											
		1 FTU			10 FTU			25 FTU			50 FTU		
Sand	Low	41.0	41.4	(41.2)	56.8	41.9	(49.4)	47.2	48.1	(47.6)	46.9	74.0	(60.4)
	High	32.4	38.6	(35.5)	44.1	45.5	(44.8)	33.0	33.2	(33.1)	44.7	44.3	(44.5)
Gravel	Low	57.2	32.3	(44.8)	38.8	41.5	(40.2)	40.1	44.1	(42.1)	36.3	38.4	(37.4)
	High	50.7	32.2	(41.4)	30.2	44.6	(37.4)	49.9	42.9	(46.4)	39.6	37.5	(38.6)

types of substrate available at these sites shows a high selection for the stable artificial substrates where the poorer sandy substrates exist (Sites 3, 4 and 10), and rejection of the artificial substrate where rubble prevails and diversity is naturally quite high (Site 6). Again the populations are dependent more on substrate characteristics than siltation. Erosion and related turbidity which does not affect the quality of the rocky substrate does not appear to alter the benthic fauna.

Fish

Cyprinidae dominated the turbid water tributaries of the Nemadji River system where species diversity was highest. Troutperch, a species characteristic of lakes and some turbid streams (27), was found only in the turbid tributaries of the Nemadji River system. Although walleye concentrated in turbid areas of Lake Superior, abundance in the Nemadji River was low. High species diversity and biomass of fish in turbid tributaries of the Nemadji River indicate that red clay turbidity is conducive to production of many small non-predatory fish. Cover provided by turbid water may increase survival of these species by reducing predation.

Lake Superior studies showed lake trout avoided turbid water. Distribution of stream trout and brook sticklebacks was restricted to clear water tributaries of the Nemadji River system. Availability of physical objectives such as riffle areas, undercut banks and large debris which serve as cover, have been found by other investigators to be primary factors regulating stream trout populations (28). These features were characteristic of clear water tributaries in the Nemadji River system but were rare in turbid tributaries and in the Nemadji River proper where nature of the soils prevents development of undercut banks, sedimentation limits riffle areas and high spring runoff combined with a mobile substrate removes debris from the channel.

Unstable sand substrate reduced macroinvertebrate production, a principle food of stream fish. Low food supply may explain the low densities of walleye found in turbid Nemadji River waters in contrast to the turbid Superior-Duluth Harbor and turbid water zone of western Lake Superior.

Fish reproduction in the Nemadji River appears to be limited to those species which do not bury their eggs in redds. Smelt embryos survived turbidity to 50 FTU in laboratory streams. Large concentrations of smelt and sucker fry observed in the river demonstrated suitable spawning sites are available for these species. Sedimentation has been shown to adversely affect trout embryo survival in redds (29, 30). Lack of suitable spawning sites may be partially responsible for the low numbers of trout or walleye in spring runs.

The individual responses of Lake Superior and Nemadji River system aquatic populations to physical-chemical changes resulting from red clay erosion should be predictable in other aquatic systems influenced by similar non-point source pollution. Lake Superior studies demonstrated that responses of individual populations to turbidity may influence species interrelationships and through this secondary effect may alter community structure. Because each population response to chemical-physical environmental change could potentially bring about several changes in species interrelationships, it would be extremely difficult to predict the occurrence of these community level responses from one system to another even with an improved data base. There is an almost complete lack of information on the effects of any form of pollution on species interrelationships. These secondary effects must be addressed by additional research if the influence of pollution on aquatic life is to be fully understood.

Information presented in this report on the Nemadji River system was based on data collected over a short time and conclusions must be accepted as preliminary. Additional work recently initiated or scheduled as part of our investigations on the Nemadji River system will help to define effects of low light penetration on primary production, behavioral responses of stream animals to turbidity and response of the system to erosion control practices.

ACKNOWLEDGEMENTS

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Non-point Source Modeling for Section 208 Planning

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In early 1975, the staff of EPA's Athens Environmental Research Laboratory was requested to assist the developing Areawide 208 program by providing techniques for assessing and/or predicting water quality and non-point source problems. Our first step was to visit several Areawide 208 organizations, EPA Regional 208 staffs, and major consulting firms to evaluate needs, levels of technical sophistication, and computational equipment capabilities.

During these initial contacts, it became painfully clear that there are still many decision-makers, both inside and outside of EPA, who do not understand, accept, or, in some cases, condone the use of non-point source models or water quality models. To me, this is a harsh indictment; not so much of those who are overly cautious, but of those of us who should be able to adequately present and explain to environmental managers the necessity and utility of applying the most powerful tools available.

Some Areawide 208 organizations have a major problem in adequately communicating the results of environmental assessments and plans to the various elected bodies within their designated 208 jurisdictions. Thus, in anticipating that others might be facing similar problems, the first part of my presentation will consider the question "Why Use Models?" and the latter portion will briefly describe the current state-of-the-art modeling tools available in the public domain for non-point source loading and water quality management.

Why Use Models?

Everyone has his own definition of "models." My definition, for non-technical people, is: Models are representations of reality having specific goals or objectives. When applied to problems of environmental assessment, models or "mathematical descriptions" may be developed for the movement of a pollutant mass through a given river basin or air shed to gain insight into benefits derived from reducing the inputs through treatment or control. For other situations, models may be used to gain understanding of the growth responses of specific organisms such as bacteria, algae, or fish when temperature, light, or nutrients are varied through prescribed ranges. In any case, the modeler or manager must have clearly stated objectives.

It must be pointed out early in our discussion that models are only "partial truths" because our ability to "represent reality" is limited by our inability to accurately perceive, measure, or mathematically describe real places, systems, things, or events. This problem becomes very evident when we attempt to describe forests, lakes, or streams that are being polluted and we realize how little we actually know about the structure of the food web or the flow of materials and energy among the various compartments of the ecosystem. In spite of this lack of knowledge, the step-by-step, systematic approach required for the development of mathematical models offers the most rational method of making management decisions relative to complex environmental issues.

In the broad sense, man has been using models to represent reality since he became a thinking being; our recorded history is full of examples. The paintings left by early cave men and the dances of the aboriginal indians depict the glories of the hunt and encounters with the most savage beasts. The Egyptians recorded their impressions of reality with pictures and symbols; and the Aztecs and Incas developed calendars to model and predict the annual progression of the seasons. Ancient Chinese and Babalonians recorded their observations of the planets from which astrological charts were developed and the possible fates of important men were predicted. The need for better methods for quantification led to the development of mathematics and systems of measurements. Navigators produced charts and maps that modeled their travels and enabled others to follow. Engineers learned to arrange their data in tables and nomographs for easy analysis and to aid in the design of equipment and structures for specific purposes. In our own time, the mathematical representation of competing physical and biological processes enabled Streeter and Phelps to model their understanding of the oxygen dynamics within a reach of the Ohio River. And now the advent of the high speed computer has enabled us to extend this early work and to assemble and analyze thousands of bits of information, represent many interacting processes, and evaluate unlimited alternative schemes for decision making.

Under this broad definition of models, each of us develops and utilizes models for every decision that we make. The model may only be in our minds, yet it involves assembly and assessment of pertinent information, weighing of alternatives, and prediction of the outcome of the alternative decisions. In some endeavors, an expert is an individual who is adept at perceiving reality through his experiences, whose decision models are good enough to enable him to make right decisions more often than not, and who is also able to describe or communicate his decision models to others well enough to gain their confidence.

Unfortunately, for those of us in the field of environmental protection, the required data bases are so large and there are so many interacting factors that a single individual can seldom track the decision process to a successful conclusion without the aid of sophisticated external tools. It is a simple and logical progression, therefore, for environmental managers to advance from the simple mental decision process to complex decision processes that utilize the best modeling tools available.

Major advantages to the environmental manager are that modeling:

- Provides better problem definition.

  In the process of developing or selecting models for specific objectives, the manager is required to carefully analyze the problem at hand and to list all of the known major contributing factors. This analysis more nearly focuses on the true cause-effect relationships that might exist and reduces the chance of treating symptoms rather than the disease.

- Provides a guide for data collection.

  When a model is developed during the initial analysis of a problem it serves as a basis for optimum data collection. Because the data are used to calibrate the model, there is usually a large dollar savings and the persistent problem of having the wrong data collected at the wrong place and at the wrong time is prevented.

- Provides a framework for assessing data.

  A well-designed model automatically provides the format for data analysis. Just as the form of the model dictates what data are required, models can also provide automated procedures for extracting rate coefficients, maxima and minima values, and other information from raw data.

- Provides ability to handle complex interactions.

  Today's environmental management problems often require tracking the transport of a pollutant through the environment in order to establish a procedure or to select a management scheme that maximizes several factors while minimizing others. Such problems may involve the interactions of so many competing processes occurring at different times and at different rates that it is practically impossible to reach a judicious solution without using the modeling process.

- Provides an ability to predict.

  Rational models that couple mathematical descriptions of the various interacting physical, chemical, and biological processes or socio-economic factors provide the capability of predicting responses to combinations of factors that fall outside of the range of historical data used for the initial model calibration. Once developed, these process models provide quick, inexpensive ways (sensitivity analysis) to determine the importance of interacting processes or factors by running the model while varying each input parameter through a real or projected maximum and minimum. The relative magnitudes of the resulting changes in the model outputs can then be used as guides for determining both the quantity and accuracy of the data required for calibration and validation. (Parameters that have little effect on the outcome of the simulated problem require less attention and resources.) Similarly, the greatest benefits to be derived by environmental managers from using simulation models result from the ability to test any number of hypothetical situations by varying combinations of input conditions through projected extreme values. Again, these extreme conditions may represent actual measured values or they may be generated by mathematical and statistical techniques (i.e., stochastic methods). The resulting range of model output values can readily be used by managers in selecting optimum solutions from the alternatives proposed. Thus, better decisions can be made even when the models are imperfect representations of reality and the data bases are less than desired.

- Allows examination of decision processes.

  Because the development of simulation models requires that all of the assumptions, data bases, and outputs be recorded, the entire decision process can be examined by all interested parties. This factor can be of great assistance when properly presented to various decision and/or interest groups whose support is vital to good environmental management.

In concluding my remarks about the utility of applying modeling techniques to solve environmental problems, I should point out that the optimum procedure requires the development of a specific model for each problem encountered. Of course, the complexity of the model depends upon the complexity of the problems. In reality, however, time and resource limitations force the direct use or modification of models that have been developed by others. Thus, the task becomes one of selecting the simplest and most economical model format that will best encompass all of the stated conditions of the particular problem.

State-of-the-Art Models

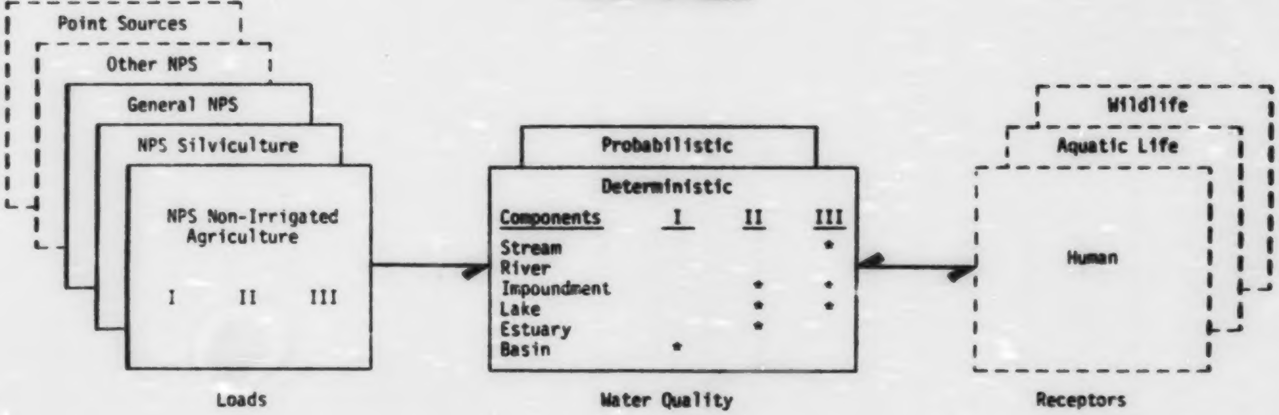
Universities, private industries, and government agencies have probably developed as many different water quality models during the past 10 years as the automobile industry has produced different model automobiles. Like the new model cars though, most of these simulation models represent minor modifications of a few very basic conceptual structures. Thus, to simplify this overview, I will discuss the differences in the basic model structures available in the public domain.

When one views the movement of pollutants through a watershed from source to undesirable impact, the significant environmental processes divide into three logical groups for modeling purposes (Figure 1).

- "Loading" models represent the inputs and movement of materials from origin to watercourses and may be developed for point or non-point sources on the land. These models interface with water quality models and provide input concentrations and rates.
- "Water quality" models simulate the movement of materials through streams, rivers, impoundments, lakes, estuaries, or entire basin systems. They generate estimates of the concentration and distribution of pollutants within aquatic systems and thus provide the vital management link between source and "level of exposure."
- "Receptor" models should interface with water quality models and simulate the uptake and dose response of humans, livestock, wildlife, aquatic life, ecosystem functions, etc. to various pollutants. These models should include chronic and acute toxicity responses to individual species and prolonged

WATERSHED MANAGEMENT

SIMULATION MODELS


Point Sources
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Aquatic Life
Human
Receptors

ecosystem impacts such as damage to food webs, effects of primary production, and rates of decomposition.

Taken together, these models give managers better tools to estimate the long-term effectiveness of control strategies by coupling the management alternatives directly to the degree of risk or safety. Unfortunately, the receptor models are not as well developed as the loading and water quality models, and the tasks of providing computer-compatible software interfacing are just beginning. For example, researchers are still looking for adequate ways to project the degree of adaptation or selection that organisms and systems experience when subjected to low-level chronic concentrations of pollutants. Thus, it will be several years before the receptor models will become available for general use.

The staff at the Athens Environmental Research Laboratory has further subdivided the loading and water quality models into three groups according to geographic scale: basin scale, 200 square miles and greater; area-wide, 200 square miles and smaller; hydrologic unit, small watershed or field. This grouping is convenient because geographic scale also limits the complexity of the models. Although technically feasible, high data acquisition and computer costs currently prohibit the general use of very complicated models for large area simulations.

Basin Scale

Basin scale models are generally used for large area problem assessment or load reconnaissance. Only gross resolution is possible, and the on-land or in-stream processes are generally limited to hydraulic transport and first order decay. Values from the Midwest Research Institute handbook (1) are used for non-point source loads and the coupled loading and water transport models can be used to identify areas having potential water quality problems based on the mass of pollutants within the system. These models should not be used for management decisions other than identifying locations within a basin where more sophisticated tools should be applied.

Although individual non-point source and stream water quality models have been available for large area application, the coupling or interfacing of separate models into a basin scale package has only been attempted recently. In fact, until this year there was no computer-compatible water quality model that could simulate the continuous transport of BOD wastes from a point source, through a small stream, through a river, through an impoundment or reservoir, and into an estuary.

To fill this need, the Athens Environmental Research Laboratory contracted with Tetra Tech Corporation to develop a basin scale reconnaissance model that will interface non-point source loading functions from the Midwest Research Institute handbook (1) with a simplified Qual. II water quality model (2) and a simplified Water Resources Engineers (WRE) reservoir model (3). The contractor has already produced a desk top, hand calculation version of this basin assessment scheme and will have a computer package with users manual available for general use by July 1977. To accompany this package, Midwest Research Institute has also contracted to provide a computer-compatible calculator and data file for the non-point source loading information now available in the MRI handbook. This automatic data file and users manual should also be available in July 1977. The non-point source calculator is designed so users can enter their own loading data, if available, or use the already published information for the general area. The weaknesses of basin scale assessment package are:

- The loading factors are based on annual average yield values derived from the Universal Soil Loss Equation.
- The mass routing through reservoirs provide only crude estimates.

Area Wide

The intermediate scale or area wide models are of greatest interest to the designated 208 organizations, their consultants, and state and Federal agencies. The needs range from reconnaissance or problem assessment schemes to sophisticated non-point source loading-water quality management models.

For problem assessment, the same model availability situation exists as described for the basin scale category. Although a number of individual non-point source and stream water quality models are available, they have not been interfaced to provide a comprehensive computer-compatible system. Thus, the MRI-Qual-II-WRE reconnaissance package can also be useful at this level. This package was designed so that the more complicated versions of the Qual. II and WRE reservoir models can be applied if higher degrees of resolution are required.

To assist a 208 agency in determining whether a non-point source problem exists within its jurisdiction, Mr. Lee Mulkey of the Athens Laboratory, developed a desk top area wide assessment procedure and presented it at several EPA Regional seminars during the past year. This assessment procedure, which will be published in part in EPA's Area Wide Assessment Procedures Manual (4), was designed to lead non-technical staff through a step-by-step analysis of their non-point source inputs. The procedure uses locally available records and information from the National Weather Service, the Soil Conservation Service, the Geological Survey, state and local water agencies, or other sources, as well as data from the MRI handbook and the EPA-USDA report entitled Control of Water Pollution from Cropland, Vol. I. Again, this procedure was not planned as a problem solving tool, but solely to help 208 agencies identify potential problems that should be addressed in greater detail by their technical staffs or consultants.

The Areawide Assessment Procedures Manual also provides a gross problem assessment scheme for designated 208 agencies and covers methods for identifying and estimating the magnitude of urban and non-urban waste sources and ranking them according to their impact on receiving water quality. The Manual also describes more refined procedures for assessing waste loads from urban and non-urban areas as well as detailed discussions of water quality management models.

Higher resolution, non-point source loading models for area wide applications are characterized by two major differences in the model construction:

1. Models are designed to simulate either continuous or single runoff events.
2. The models either assume all pollutants to be associated and transported with sediments or simulate the transport of pollutants in both the dissolved phase and in association with the sediments.

The most commonly used urban runoff models, SWMM (5) and STORM (6) both handle pollutants as associated with particulate materials. The initial version of SWMM is a single runoff event model and is more complicated to set up; however, it provides a number of hydraulic options that are useful in simulating complex urban situations. Recently, a simplified version of SWMM that provides for continuous simulation has become available. STORM provides for continuous simulation and is simpler to operate; however, it handles only surface runoff and is thus more limited in its application.

For non-urban agricultural areas, the most commonly used non-point source models are NPS (7) and ARM (8). NPS was designed for continuous simulation of runoff from five different land use categories (including urban); however, it can only handle pollutants that are associated with sediment transport. ARM, on the other hand, was designed initially to simulate the continuous runoff of pesticides from row crop agricultural areas and can represent the transport of pollutants in the dissolved phase as well as those sorbed onto sediments. The ARM model is currently being modified to include nitrogen, phosphorus, and organic carbon as BOD from field and animal wastes. The modified version should be available for general use by July 1977.

A major weakness in the application of area wide management model packages has been the incompatibility of the loading models with the in-stream water quality models. A basic hypotheses for developing the non-point source loading models is that the pollutants originating from urban and agricultural areas move into watercourses with storm waters either during or just after rainfall events. As stated earlier, these pollutants are transported either in the dissolved phase or attached to sediment particles and all but one of the commonly used loading models represent only the sediment associated materials.

Contrarily, the most prevalent water quality models were designed to represent constant point source inputs to steady state average low flow, stream conditions. Because of their limited mass balance assumptions, these models only simulate pollutants in the dissolved state or those conservative materials that move with the bulk water without change. They are also highly structured to simulate the oxygen dynamics within the receiving waters. Thus, it is obvious that the original objectives for developing the two types of models were completely different, that the structures of the models are generally incompatible, and that in those situations where in-stream sediment transport (sedimentation, scour, bank erosion, sorption, and desorption) are thought to be important, Qual I (9), Qual II (2), Auto Qual (10-11), and DOSAG (12) water quality models will provide poor simulation results if coupled with STORM, SWMM, ARM, or NPS.

The major exceptions to this somewhat gloomy situation is the recent application of the EXPLOR (13) and LINSED-CHNSED (14-15) series models. These models apply the principal of momentum as well as mass balance and simulate the movement of volumes of water flowing downstream. This basic structure permits easier simulation of sediment dynamics as well as other processes that take place along the wetted perimeter of streams.

To further improve modeling compatibility, Athens Environmental Research Laboratory is currently negotiating a contract to modify the structure of Qual II to permit pollutant-sediment interactions and dynamics to be simulated with the mass balance model structure.

Lake and reservoir models for the area wide category also divide into two general groups according to their capability to simulate hydrodynamics or the chemical-biological properties of the water bodies. The Battelle Deep Reservoir Model (16) and the WRE Reservoir Model (3) exemplify models providing relatively good hydrodynamic simulations with less well developed chemical-biological properties. Conversely, the IBP Eastern Dediduous Forest Biome Model series CLEAN-CLEANER (17-18) provides very detailed food web, organism growth, preditor-prey, production-decomposition, and nutrient uptake-regeneration simulation capabilities for a water column within a lake. These ecosystem dynamics models do not have adequate hydrodynamics programs to move the water masses between water columns to simulate the flow and mixing patterns within entire impoundment reservoirs or lakes. None of the models are capable of adequately representing non-point source inputs directly into the water bodies.

Further development activities are currently improving the chemical-biological processes in the hydrodynamic models, and the Athens Laboratory has negotiated a contract to improve the hydrodynamics subroutines within the lake ecosystem models.

Hydrologic Unit or Field Scale

The hydrologic unit category of models includes the complex process models that are being developed to simulate the application, volatilization, sorption-desorption transport, transformation, degradation, etc. of specific pollutants within a small portion of a watershed. These models include both on-land and in-stream processes, and calibration data are required for both the specific pollutants considered and for the terrestrial and aquatic ecosystems being polluted. The ARM pesticide model was developed initially for small watershed application, and there are a number of separate in-stream fate and transport models under development for various organic and inorganic substances. At this time, the integration of the hydrologic unit-loading models with the in-stream process models is still in the research stage and, although such couplings have been made, the model packages have not been generally applied and tested. One such interfacing was accomplished last year by Dr. James Falco and Mr. Lee Mulkey of the Athens Environmental Research Laboratory when they coupled an ARM model calibrated for the organophosphorus pesticide malathion with an in-stream process model covering microbial and chemical degradation with a fish (bluegill) receptor subroutine. The aquatic portion of the model agreed reasonably well with test results obtained in the Laboratory's Aquatic Ecosystem Simulator and the entire package demonstrated the feasibility of interfacing these complex models and developing realistic environmental management alternatives.

The hydrologic unit models are very complex and require relatively large amounts of calibration data and computational time. Once developed, however, these detailed process models will simplify interfacing problems and provide optimum environmental management tools for state area wide 208 agencies.

In conclusion, it is obvious that a large number of individual non-point source and water quality models representing wide ranges of complexities and possible applications are available. Greater progress, however, must be made in interfacing these models into environmental management packages. At present, however, compatible packages can be assembled to represent or simulate many local problems. And, even though these model packages are known to have deficiencies in certain areas, the judicious application of these models for simulating management alternatives using high-low and average conditions offers the best available assistance for the decision-making process.

Acknowledgment

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TILE DRAIN SIMULATION MODEL

by

A. B. Bottcher*

A computerized simulation model is being developed at Purdue University to provide a predictive tool for the determination of sediment losses from tile effluent. The model will provide a flow hydrograph with associated sediment loading as a function of the input variables (rainfall and initial soil moisture content). The model will have the capability of being modified to represent different tile system designs and soil types.

The need for concern of tile drainage influence on water quality is shown by the significant contribution it has to stream flow. Approximately 50% of the Black Creek Watershed is drained by subsurface tile systems. A tile system can contribute anywhere from 10 to 100% (typically 30%) of the total runoff of a drained area. This indicates that approximately 15% of the runoff per year from Black Creek is tile effluent. During non-storm periods tile effluent is the major source for stream flow in agricultural areas. The influence of tile flow on stream flow may vary greatly depending on the annual rainfall distribution.

An estimate of the sediment, phosphorous and nitrogen going into the Maumee River from Black Creek tile effluent is approximately 100, 3 and 9 kilograms per hectare per year, respectively. Note that a kilogram per hectare is approximately equal to a pound per acre. This is based on the previous flow assumption and tile effluent data collected on about 266 tile outlets in the Black Creek Watershed. The loading rates of localized areas can be much larger as shown by G. O. Schwab (1). He measured annual sediment losses from tiles as high as 5400 kg/hect/year. His results indicate that in some critical areas the tile effluent may be the dominant effect on stream water quality.

BACKGROUND

Glacial tilled soils of the Midwest seem to be very susceptible to erosion losses through tiles. The soils drained by tiles generally have high silt and clay contents. These fine particles are able to be detached and transported within the soil profile by forces exerted on them by flowing water. The actual detachment and transport mechanisms within a soil profile are not well understood. Many studies have been done in closely related areas such as piping effects and force balance relationships within soils.

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A model by D. Zaslavsky (2) describes the force balance of particles in cohesive soils. This model also shows the implied inter-relationship of flow gradients to the fine particle movement. Particularly it indicates that for a given particle size a threshold flow level must be reached before particle movement will occur. The effect of the flow channel size on the threshold flow is also provided. Zaslavsky's model uses these relationships to obtain an expression which relates the critical (threshold) flow for particle movement to a given particle size assuming a mean pore channel size. To extend the use of Zaslavsky's model for an erosion yield model it becomes necessary to attach a probabilistic detachment model to the basic force balance relationships. Thus a probability is associated with the critical flow and has a functional relationship to flow above the critical flow. So for a given particle size and flow rate it is possible to show a distribution of detachment potential for a particle size distribution. The probabilistic approach used by H. A. Einstein (3) provided excellent results for particle detachment and transport in open channels.

The particle detachment model described above requires knowledge of the water flux distribution within the soil profile. Several tile flow models (4) are available, but none are uniquely suited for a tile erosion model. Therefore a two-dimensional porous medium flow model will be developed to provide the necessary water flux distribution within the soil profile. The flow in the unsaturated profile region will be determined by Darcy's Law which is the tension-conductivity method. The flow at the tile will be tentatively determined by Toksoz and Kirkham's formula (5) using the watertable height above the tile. This tile flow formula was developed for a constant infiltration rate passing through an unsaturated layer into a saturated layer. This indicates continuity at the watertable which is required to effectively model across this transition layer. Continuity is expressed as:

Change in water storage = Inflow - Outflow

Now using the assumption that a known geometric flow pattern exist near the tile, the magnitude of water movement near the tile can be generated as a function of R and θ (radial distance and angular direction from tile, respectively). Flow nets are available for several different soil profiles above tiles (6). The water flux is then used to determine the relative volume of soil which is experiencing a certain erosion potential and then these volumes are summed for all erosion potentials for given particles sizes to determine total erosion potential. As indicated the sediment loss is determined as a distribution shape and therefore absolute magnitudes are not directly provided by this approach. Field data will be needed to quantify the sediment loss distribution.

THEORETICAL MODEL FOR PARTICLE DETACHMENT

The forces acting on a soil particle can be summarized as:

F_g - gravitation force
F_c - cohesive force (attraction between particles)
F_h - hydraulic forces (caused by water movement)
F_p - point forces (caused by physical contact with other particles)

It is intuitively clear that to get particle movement, the hydraulic forces F_h must exceed the sum of all the other forces, that is,

$$F_h > F_g + F_p + F_e$$

Gravitation Force

The effective gravitation force is the submerged weight of a particle.

$$F_g = V(G - 1)\ \gamma_w$$

The variables in above expression are described as follows: V is the volume of the particle, G is its specific gravity and γ_w is the unit weight of water. It is of course possible for the gravitation force to be in any direction with respect to the detachment force F_h. However direction will be taken care of, because all forces are represented as vector quantities.

Cohesive Forces

Cohesive forces are the result of electrostatic-interactions of very small particles. These forces are not well understood, but they can be related to the overall tensile strength (ease of pulling apart) of a soil. Cohesion is normally determined by the amount of stress to cause a failure in shear for a zero load on samples. The overall cohesive force per unit area, which can be measured as above, can be represented as the sum of all the individual cohesive forces for each particle in the layer of shear.

$$\frac{\text{Cohesive Force}}{A} = \sigma = a_1A_1\sigma_1 + a_2A_2\sigma_2 + \ldots\ldots\ldots + a_nA_n\sigma_n$$

or

$$A\sigma = A\sigma \int f(D)dD$$

therefore,

$$F_c(Di) = \frac{A}{f_i\ n} \cdot \int_{(D_i - \Delta D)}^{(D_i + \Delta D)} f(D)dD$$

The variables in above expressions are described as follows: A is area of test sample, σ is failure stress of test sample, a_i is a geometric factor for the ith particle shape, A_i is the area of the ith particle area which is influenced by the shear-stress, σ_i is the stress of the ith particle, n is the number of particles in the test layer, D is a particle size, f_i is the fraction of particles in the ith particle interval which has a $2\Delta D$ width. The density function $f(D)$ should be proportional to the square inverse of the particle size and directly proportional to the particle distribution.

Hydraulic Forces

A particle experiences drag and lift forces when flowing water passes over the given particle. The sum of these forces is equal to the overall hydraulic force, that is,

$$Fh = F_{lift} + F_{drag}$$

Drag forces are given by Stokes Law:

$$F_d = \frac{2\ 4Ap}{R_e} \frac{\rho Vs^2}{2}$$

Parameters are described as follows: Ap is the effective area factor (accounts for particle size exposed to the stream flow V_s, R_e is Reynold's Number, and ρ is the density of water.

The lift force on a particle is developed when the water flows faster over one side of the particle than the other. The lift force for an attached particle can be expressed as a function of its exposed surface and the velocity of water across its surface V_b.

$$F_L = C_L K_1 D^2 \rho \frac{V_b}{2}$$

Parameters not previously described are as follows: C_L is lift coefficient and K_l is exposed surface factor.

Ratio of Non-Point Forces

For particle detachment the hydraulic force must exceed the sum of the cohesive and gravitational forces or expressed as a ratio.

$$\frac{F_g + F_c}{F_h} = R < 1$$

If the ratio R is less than unity then the potential for erosion exist. However the above expression assumes that all particles of the same size experience the same cohesive force. This is not the case, so a normal distribution will be assumed such that a probability with exist for particle detachment for R's slightly greater than one. This serves to smooth out the computer summation of the erosion potentials.

Point Forces

The point forces are impossible to describe for any one particle. The magnitude of these forces can be very large, but intuitively one can reason that only the particles near a free surface will have any possibility of small or no point forces. Within a soil profile only the smaller particles (clay and silt) will see free surfaces in the pore cavities and channels. A probability p for detachment must be associated with each particle size D to account for the point forces. Now the probability of detachment is the probability that the point force F_p is less than all the other forces, that is,

$$\text{Prob}\ [F_p < F_h(1-R)] = p(D,R)$$

This functional relationship of p will vary by soil type and depth in profile. Laboratory experiments are needed to determine this relationship. Present plans are to fully investigate the Hoytville silty clay soil type (most common in Black Creek) before extending the laboratory experiments to other soil types.

Discussion

Several of the relationships presented are not easily determined experimentally. Therefore, some assumed relationships will be used initially until reliable laboratory data is avilable. The accuracy of the model to predict actual erosion losses will serve to validate or disprove assumed relationships. It should be noted that all forces are vector quantities and therefore the numeric analysis of the erosion model will be more complex than indicated in this paper.

The time dependence of the detachment mechanism is represented by the probabilistic relationships of the point forces and hydraulic forces. In order to change the erosion potential of a particle either the flow must change or another particle near it must move. So over time the loss of surface particles increases the probability of detachment of particles beneath the surface layer. Armoring will occur over time, but for this model it is assumed that natural soil weathering will periodically recharge the smaller particles in the pore cavities and channels.

To use the particle detachment model, it is convenient to combine the probabilistic and force balance relationships into one erosion potential expression for a tile system. The detachment model will provide a fraction of particles detached per unit area per unit time f_i for the particle distribution interval $[D_i+\Delta D, D_i-\Delta D]$ at a given water flux. Define erosion potential as the ratio of erosion rate at tile flow TQ to the erosion rate at maximum tile flow TQ_{max}. It is now possible to compute the erosion potential at a TQ by making the assumptions of a geometric flow net and the same soil texture throughout the profile. The computation requires an integration over the entire soil profile for each particle size interval used and these results added together. For Zaslvasky's relationship and a radial flow assumption the erosion potential is given as:

$$EP = \frac{\Sigma\, f_i \left(\frac{TQ}{Q_{cr_i}} - 1 \right]}{\Sigma\, f_i \left(\frac{TQ_{max}}{Q_{cr_i}} - 1 \right]}$$

The parameter Q_{cr_i} is the critical flow for a given particle size D_i.

COMPUTER MODEL

The tile model is programmed in the GASP IV Simulation Language. GASP IV was selected because of its advanced time stepping and differential equation solving techniques. The computer model breaks the soil profile above the tile into N layers (see Figure 1). Hydraulic conductivity for each layer can be provided separately. This gives tremendous latitude in the types of soil profiles which can be analyzed. Flow between each layer is determined for each time step

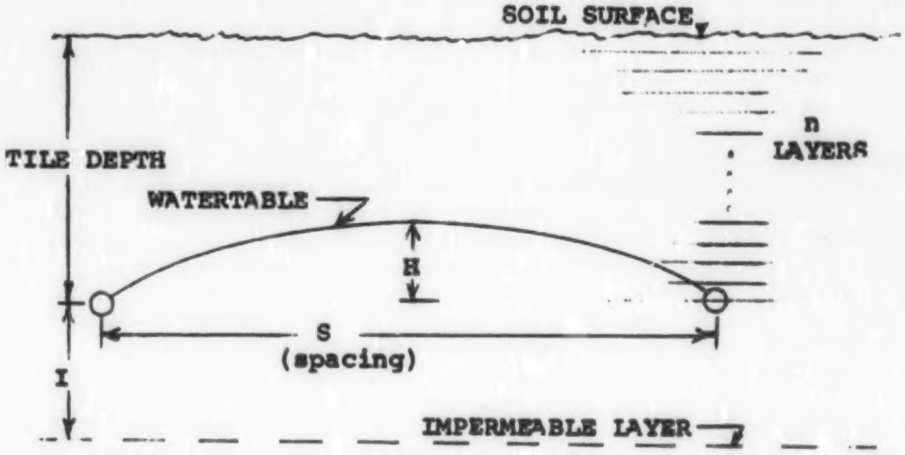

Figure 1. Tile System Layout

by use of Darcy's Law.

$$q = k[\partial(T+Z)/\partial Z]\Delta t$$

Continuity at the watertable is determined by comparison of the flow into the layer in which the watertable is located and the flow out the tile as determined by Toksoz and Kirkham's method.

$$\text{TQ (tile flow)} = \frac{KH}{SF+H}$$

Parameters described above are as follows: q is vertical water flux, K is hydraulic conductivity, T is tension head, Z is elevation head, t is time, H is height of watertable above tile center, S is tile spacing and F is geometry coefficient for the tile system layout. Initial attempts will use Zaslavsky's piping relation, Q_{cr} = ftn (D), and associated erosion potential. The probabilistic model will be added when fully developed.

The computer model solves the above relationships for any rainfall distribution provided. The output of the model is a plot and table of tile outflow and sediment loading rate as a function of time. Also at any time during the simulation a moisture plot can be obtained for the soil profile above tile.

Discussion

A similar problem exists for the hydraulic model as in the detachment model, that is, some of the parameters are not readily available and when available are in a graphic form. Graphs are empirically hard to represent in a computer program if they do not have a nice functional relationship (equation) which will represent them. This is the problem with many of the required parameters for the tile erosion model. The relationship of tension and hydraulic conductivity exhibit hysteresis which further complicates exact determination. Because of these determination problems it allows linear assumptions to be made for some of the relationships. Linearization will be done so that the parameters representation will be within obtainable experimental error. Linearization also greatly increases the efficiency of the computer program.

MODEL CALIBRATION USING TILE SAMPLER DATA

The need for field data to calibrate and verify the computer model is essential. As indicated the sediment loss potential as determined by the model does not provide absolute magnitudes of the sediment loss directly. To calibrate this potential distribution at least one water quality sample is needed during a significant flow period. This in itself does not assure that the computed shape of the potential distribution is correct. Therefore, it is necessary to have water quality data for as many flow conditions as possible in order to compare the distribution shapes of both the actual and simulated sediment loss curves. To obtain this data base an automatic pumping tile sampler was installed on a tile line draining forty-three acres of a typical soil type (Hoytville) of the Black Creek Watershed.

Automatic Tile Sampler

An automatic tile sampler has been operational since March, 1976. Only one tile event has occurred since its installation. The peak flow periods for tiles are during the winter and spring months, so adequate data for calibration and verification of the tile model should be available by late spring of 1977. This pump sampler data will also be analyzed to provide loading rates directly for the determination of the tile effluents effect on water quality. The fertilizer nutrients will also be looked at closely to find their loss rate through the tile system.

The operation of the tile sampling station is somewhat unique in that discrete water quality samples are collected proportionally to the tile outflow, which is continuously monitored and recorded. The time at which a sample is collected is also recorded on the flow hydrograph chart. The sampler has the capability of collecting 72-500 ml water samples. The sampling rate is approximately 1 sample per 30 minutes at maximum flow. Another feature of the tile sampling station is the prevention of the tile outlet from becoming inundated. This is necessary to provide reliable data during storm events in which the ditch water level is above the tile outlet. Two 200 GPM pumps used in conjunction with a sump will maintain a free water fall over the flow calibrated weir. Pump "on" times are also recorded to provide a check for the water volume passing through the station. See Figure 2 for more detail of the tile monitoring station.

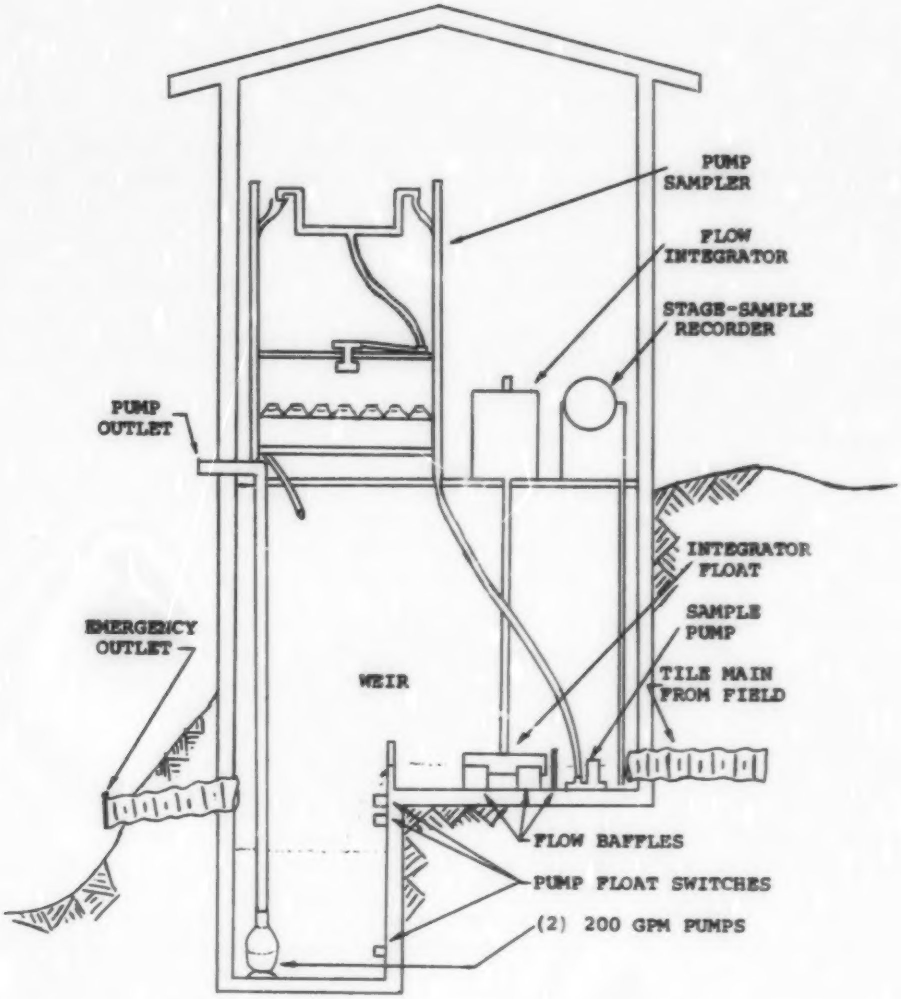
PUMP SAMPLER
FLOW INTEGRATOR
STAGE-SAMPLE RECORDER
PUMP OUTLET
INTEGRATOR FLOAT
SAMPLE PUMP
EMERGENCY OUTLET
WEIR
TILE MAIN FROM FIELD
FLOW BAFFLES
PUMP FLOAT SWITCHES
(2) 200 GPM PUMPS

Figure 2. Automatic Tile Sampling Station

Data collected for the single event on April 26-30 shows a sediment loss of approximately 6 kg/hectare. The peak concentration of suspended solids was 279 PPM. Tile outflow peaked at .0036 cubic meters/sec (~ 60 gal/min). Tile flow was caused by a 4.1 centimeters rain storm. The above data is in good agreement with data collected for several tile systems draining Hoytville soils in the Black Creek Watershed.

SUMMARY

The tile erosion model with associated hydrologic model should be operational by August 1977. The laboratory determination of required relationships will begin in January, 1977. The hydrologic model is working for the linear assumptions presented in this paper. The tile sampling station is functioning and should be collecting water quality samples for the next year to determine tile effluents effect on stream water quality and provide a means to calibrate the drain tile erosion model.

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BEST MANAGEMENT PRACTICES FOR URBAN STORM AND COMBINED SEWER POLLUTION CONTROL
A CASE STUDY

Cornelius B. Murphy, Jr.

Best Management Practices Seminar
For Non Point Source Pollution Control

Rosemont, Illinois
November 17, 1976

O'Brien & Gere Engineers, Inc.
Syracuse, New York

The 1972 Council of Environmental Quality Third Annual Report indicated that in 80% of the urban areas studied, downstream water quality was not controlled by point sources. The urban contribution to these water quality contraventions is in the form of stormwater and combined sewer overflow discharges.

The extent of the problem contributed by combined sewer overflows and stormwater discharges is put in proper perspective if one realizes that one fifth of the nation's population is served by combined sewer systems. Furthermore, ten (10) of the nation's fourteen (14) largest cities are served by a combined system in whole or in part.

In light of the very significant capital and operating costs associated with the application of capital intensive storage/treatment alternatives, the application of Best Management Practices (BMP) offers itself as a very attractive alternative to the solution of wet weather induced water quality impairment. A BMP program has been developed as a first phase solution to the combined sewer overflow problem presented by the Rochester, New York combined sewer system. The following is a summary of the configured program, the methodology of approach required to develop the program, and the cost/effectiveness of the BMP solution.

BEST MANAGEMENT PRACTICES

A rational and cost/effective solution to the abatement of both stormwater and combined sewer overflow involves the application of the concept of Best Management Practices (BMP).[1] A BMP program focuses on the sources of pollutants and their means of conveyance. Integral to a total BMP program is source and collection system management. A breakdown of the various elements of a BMP program is shown in Figure 1.

Source management involves the application of measures to reduce or prevent pollutant loading before surface runoff enters the conveyance system. Typical source management abatement measures include the application of surface flow attenuation, use of porous pavement, erosion control, restrictions on chemical usage, land use planning, and improved sanitation practices including trash removal and street cleaning.

Collection system management involves the application of all abatement alternatives which pertain to the collection system. Collection system management alternatives therefore involve all those abatement alternatives applicable after the

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1. "Best Management Practices - Urban Runoff Sources of Water Pollution," EPA Draft Publication, February, 12 (1976).

runoff enters the collection system. Typical solutions fall into two basic categories, structural intensive and minimal structural. The collection system management alternatives which are of interest in a BMP program involve those requiring the expenditure of minimal resources. Relevant collection system management practices involve inflow/infiltration control, improved system regulation, optimized system control, polymer addition for friction reduction, and minimal improvements to make the collection system self consistent (elimination of conveyance systems throttling constraints).

METHODOLOGY OF APPROACH

There are a number of very detailed and complex steps that must be undertaken prior to the selection of a combined sewer overflow abatement program. These steps are required regardless of whether one is configuring a BMP program or a conventional structurally intensive program:

- Definition of Existing Conveyance and Treatment Systems
- Definition of Catchment Area Characteristics
- Review of Meteorological Data Base
- Selection of a Detailed Network Model
- Initiation of an Overflow and Meteorological Monitoring Program
- Establishment of Relevant Abatement Alternatives
- Use of Simplified Model to Evaluate the Existing System - Long Term Simulation
- Initial Evaluation of Storage/Treatment Structural Alternatives Using Simplified Model
- Calibration and Verification of the Detailed Network Model
- Application of the Detailed Network Model to the Preliminary Evaluation of the Non-Structural Alternatives
- Selection and Verification of the Wet Weather Water Quality Predictive Models
- Process Evaluations of Applicable Treatment Processes - Central vs On-Site
- Detailed Analysis of the Prime Structural Intensive Alternatives

- Determination of the Proper Balance Between Structural and Non-Structural Intensive Abatement Alternatives and Establish Implementation Schedule

Any combined sewer overflow study must involve the full development of each of the above outlined steps in order to arrive at a cost/effective abatement program.

APPLICATION OF THE VARIOUS MODELING TOOLS

The basic modeling tools, input data requirements, model interrelationships and program output are presented in Figure 2. Mathematical models such as those presented can be very helpful to both the planner and the design engineer in conducting the cost-effectiveness evaluations for abating pollution resulting from combined sewage overflows. The five basic models utilized in the Rochester, New York evaluations include the Simplified Stormwater Management Model (SSM) originally developed by Metcalf & Eddy, the EPA SWMM Version II, the various Process Cost Benefit models, an alternative Cost Optimization model as well as the receiving stream water quality model.[2]

In order to minimize the abatement program manpower and computer costs, it has been shown that the use of a simplified stormwater model is desirable in the early stages of an abatement program. The use of a simplified model such as STORM or the SSM is ideal in the initial phase of a combined sewer study. In addition to minimizing costs, the early use of a simplified model promotes total system consciousness on the part of the user, facilitates a quick fix of abatement measures, and enhances the orientation toward attaining outlined program objectives.[3]

The SSM appears to offer the greatest number of advantages as a scanning or preliminary modeling tool. The model requires only four drainage area and collection-conveyance parameters for input information: the area of the defined catchment basin, the percent imperviousness, and the sewerage network configuration and capacity as well as an extensive rainfall record. The program requires only a minimum amount

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2. "Alternative Analysis Studies" and Network and Water Quality Modeling Studies" Combined Sewer Overflow Abatement Program Draft Final Report, EPA Grant No. Y005141, November (1976).

3. C.B. Murphy, et.al., "Network Model Comparison - SWMM, Dorsch Consult, and Simplified SWMM - Rochester, New York" Presented at SWMM Users Group Meeting, Toronto, Canada (1976).

of computer storage and computational capacity (5K) and is well suited to handle terminal interaction.

Upon the initial screening of abatement alternatives, a more complex model is required to obtain a more refined mix of the alternative requirements and subsequent effectiveness. SWMM Version II with the WRE transport block was utilized to conduct the second level of abatement alternative analysis. The WRE transport block can be utilized to define the effectiveness of various source management techniques as well as to define areas of flooding by means of backwater and surcharge analyses.

Input data sets required for the application of SWMM in addition to that utilized by SSM include domestic and industrial flows as well as infiltration and inflow (I/I) data. A more detailed definition of land use as well as a more finely defined network is also required for the optimum use of SWMM.

Several process cost benefit models are proposed to be utilized to evaluate the treatment alternatives. Required input information includes the treatment train definition, development of area specific weighting factors and critical CSO wastewater characterization information. The storage and treatment cost benefit models are then meshed with a cost optimization model to yield the optimized alternative configuration.

The network model output taken together with the process cost benefit is then meshed with the output from the water quality model to establish the program cost effectiveness. The output of the modeling effort assists in the selection of an optimum solution or series of solutions to eliminate the discharge of untreated wastewaters. The modeling effort as configured will allow the evaluation of the effectiveness of structural intensive, minimal structural and non-structural alternatives.

BMP IMPLEMENTATION RECOMMENDATIONS-ROCHESTER, N.Y.

As a result of the extensive network modeling, water quality modeling and treatment process cost/benefit analysis, a BMP program has been developed as a first phase of an overall combined sewer overflow abatement program. The following elements serve as the heart of the BMP program:

- Interceptor Improvements
- Blockage of High Impacting Overflows
- Overflow Weir Height Adjustments
- Regulator Modifications

- Addition of Control Structures
- Preparation and Implementation of Control System
- Program of Improved System Maintenance
- Preparation and Implementation of Source Control Regulations

As source control measures, it is proposed that a more intensive effort be extended in the area of sewer maintenance. It has been shown that the level of conveyance system maintenance significantly reduces the impact of combined sewer overflows. System maintenance not only helps to eliminate or minimize the first-flush phenomenon but also alleviates surface flooding problems.

It has also been recommended that the extent and effectiveness of street sweeping be increased for certain catchment areas. This is an effective method to reduce the surface accumulation of pollutants. Control over street cleaning frequency and efficiency can be an effective method for reducing the solids, toxicants, and oxygen demanding constituents discharged to the receiving waters by both the combined sewer overflows and stormwater discharges.

Other recommended source control measures include the implementation of planning concepts to minimize percent imperviousness in future growth areas, the application of porous pavement in selected catchment areas, and the implementation of erosion control measures.

As collection system measures, it is proposed that modest improvements be made to the main conveyance interceptor to the treatment facility (St. Paul Boulevard Interceptor), that modifications be made to those regulators located at the point of confluence of the trunk sewers and the main conveyance interceptor, and that the selective blockage and weir elevation increases be made to high impacting overflows. The proposed improvements to the main interceptor involve the increase in conveyance capacity of approximately five selected sections of the interceptor. This will make the interceptor self consistent with regard to conveyance capacity.

Figures 3 and 4 show the effect of implementing the BMP program on the reduction in combined sewer overflow on an average annual basis and from the two year design storm, as well as the reduction of annual average and two year design storm TKN, TSS and BOD_5 loadings. Figures 5 and 6 show the reduction in potential dissolved oxygen contravention of the Genesee River and the reduction in potential Ontario Beach closing days predicted upon implementation of the various abatement measures.

It is projected that the abatement measures outlined under the BMP program upon implementation will reduce the annual discharge of combined sewer overflows to the Genesee River by approximately 85 percent. Under the application of the 2 year-2 hour design storm it is projected that the combined sewer overflow discharge to the Genesee River will be reduced by about 25 percent. The BMP abatement measures are projected to reduce the average annual potential days of dissolved oxygen contravention from approximately ten per year to approximately one per year. The corresponding reduction in potential annual average beach closing days are projected to decrease from three per year to approximately one per year.

CONCLUSIONS

The application of a Best Management Practices approach to combined sewer overflow abatement has a number of very significant advantages over the application of structurally intensive solutions. The most significant advantages of the BMP approach are outlined as follows:

- Addresses Pollutant Reduction at the Source
- Provides for More Cost/Effective Solution
- Insures Greater Reliability
- Involves Less Intensive Allocation of Resources
- Emphasizes Optimal Operation of Existing System
- Leads to a Quickly Facilitated Solution
- Secondary Problems are Less Likely to Develop

A Best Management Practice program has been developed for the Rochester, New York combined sewer system. The BMP program for the City of Rochester is expected to involve an expenditure of approximately twelve (12) million dollars compared to the structurally intensive tunnel storage/high rate treatment system which is anticipated to involve an expenditure of nearly two hundred (200) million dollars.

The application of the BMP program for the City of Rochester is projected to reduce the average annual volume of combined sewer overflow discharged to the Genesee River by approximately 85-90%. This compares to the structurally intensive solution (based on the two year design storm) which is projected to reduce the annual average of CSO by approximately 98%.

As a result of our studies on the Rochester combined sewer system, it is recommended that a phased abatement program be developed as a solution for combined sewer overflow and stormwater systems. Through the application of a BMP program as a first phased solution, a more defined and optimally designed structurally intensive solution can be developed. By working with existing facilities and making them as effective as possible, the likelyhood of over or under design of second phase facilities would be minimized. The BMP program can also be readily implemented and as a result, receiving stream water quality improvement should be quickly realized for a relatively minor investment.

ACKNOWLEDGEMENTS

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FIGURE 1

COMBINED SEWER OVERFLOW AND STORMWATER
BEST MANAGEMENT PRACTICES (BMP)

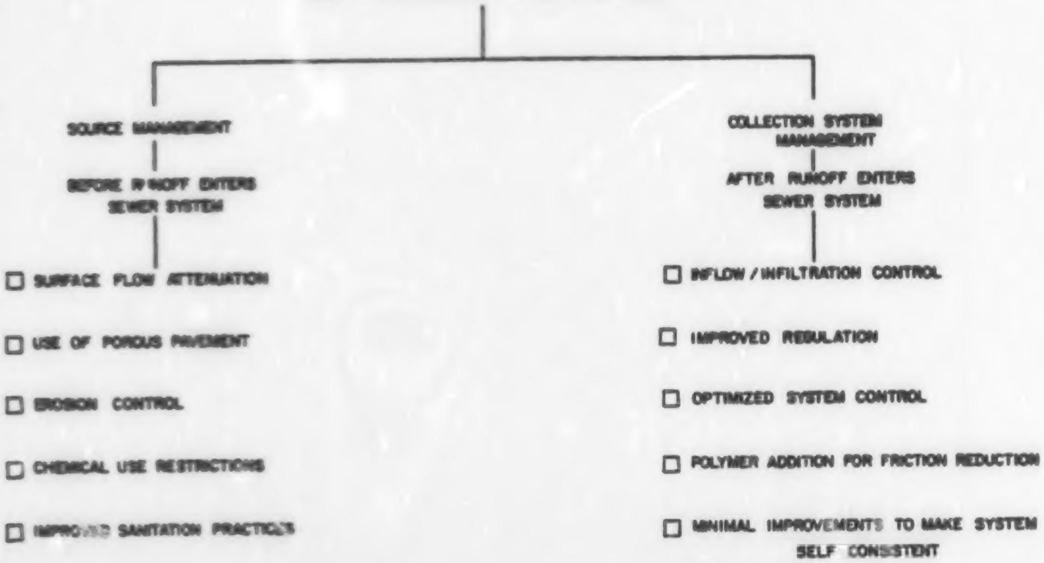
SOURCE MANAGEMENT
BEFORE RUNOFF ENTERS SEWER SYSTEM
☐ SURFACE FLOW ATTENUATION
☐ USE OF POROUS PAVEMENT
☐ EROSION CONTROL
☐ CHEMICAL USE RESTRICTIONS
☐ IMPROVED SANITATION PRACTICES
COLLECTION SYSTEM MANAGEMENT
AFTER RUNOFF ENTERS SEWER SYSTEM
☐ INFLOW / INFILTRATION CONTROL
☐ IMPROVED REGULATION
☐ OPTIMIZED SYSTEM CONTROL
☐ POLYMER ADDITION FOR FRICTION REDUCTION
☐ MINIMAL IMPROVEMENTS TO MAKE SYSTEM SELF CONSISTENT

FIGURE 2

DIAGRAM FOR MODEL UTILIZATION

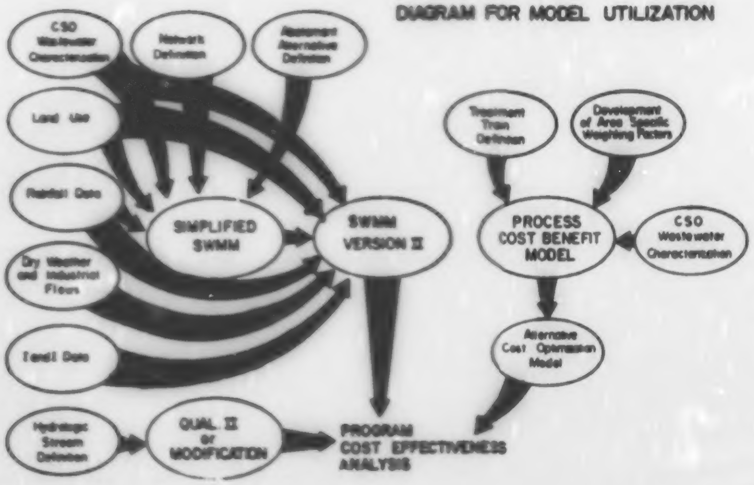
CSO Wastewater Characterization
Network Definition
Treatment Alternative Definition
Land Use
Rainfall Data
Dry Weather and Industrial Flows
Tidal Data
SIMPLIFIED SWMM
SWMM VERSION II
Treatment Train Definition
Development of Area Specific Weighting Factors
PROCESS COST BENEFIT MODEL
CSO Wastewater Characterization
Alternative Cost Optimization Model
Hydrologic Stream Definition
QUAL II or MODIFICATION
PROGRAM COST EFFECTIVENESS ANALYSIS

FIGURE 3

TOTAL SYSTEM OVERFLOW REDUCTION

RESPONSE TO IMPLEMENTATION OF ABATEMENT MEASURES

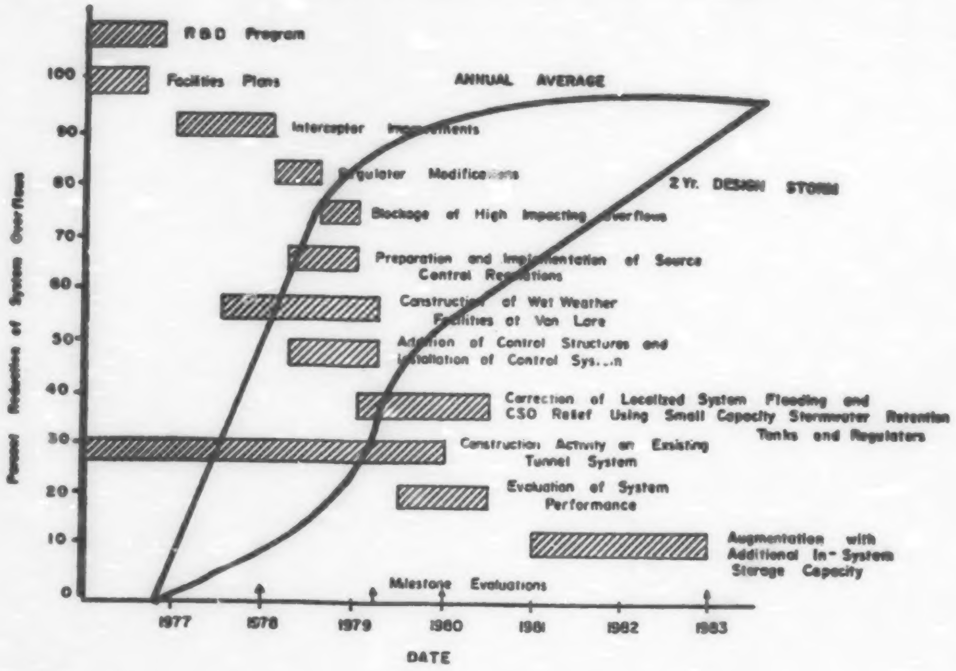

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FIGURE 4

Total System Pollutant Loading Reduction To The Genesee River
Response To Implementation Of Abatement Measures

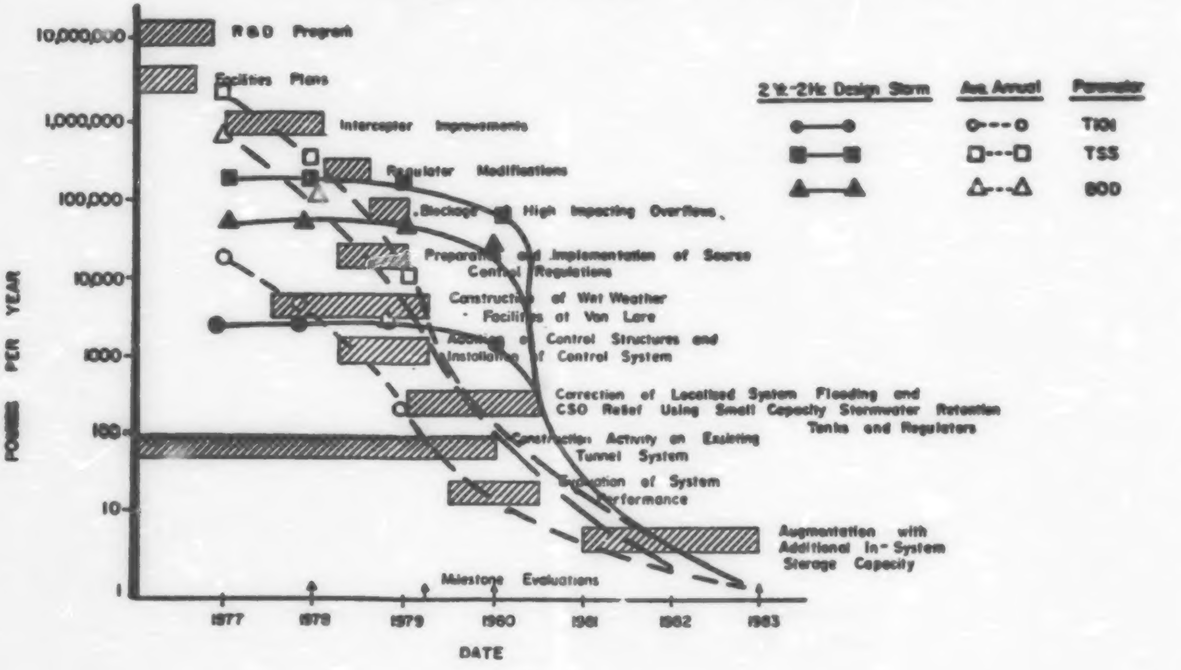

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FIGURE 5

Genesee River Reduction In Potential Dissolved Oxygen Contravention Response To Implementation Of Abatement Measures

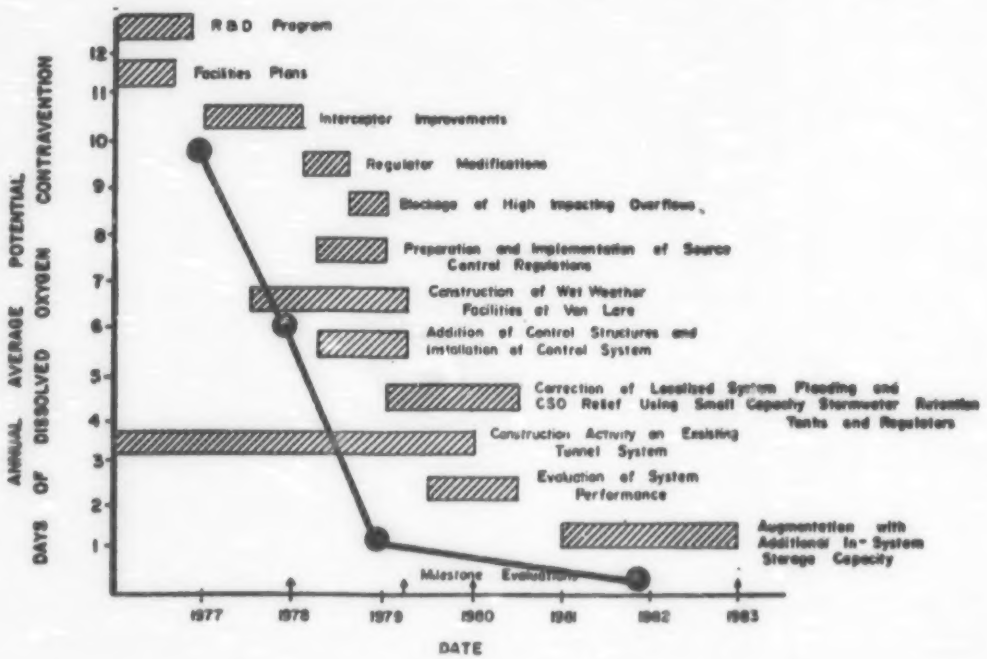

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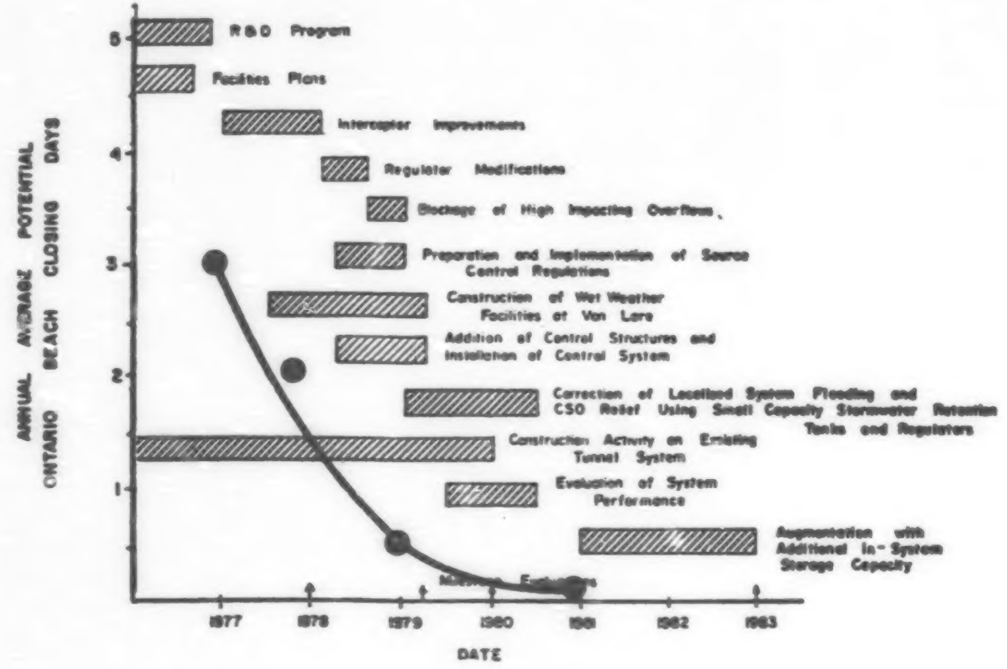
FIGURE 6

Reduction In Potential Ontario Beach Closing Days
Response To Implementation Of Abatement Measures



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SIMULATION OF THE ENVIRONMENTAL IMPACT OF LAND USE ON WATER QUALITY

by

D. B. Beasley*

Increasing emphasis is being placed on the quality of the water in the streams, rivers, and lakes of our nation. Until recently, most of the effort to improve or maintain natural water quality has been in the area of point source pollution. There are several good reasons for this approach. First, and probably foremost, the source can be easily identified and monitored. Second, discharge rates are usually uniform and the effluent, in most cases, is of consistent make up. Finally, the effects of point sources of pollution on a stream system can be and are being simulated on a routine basis.

The water quality picture, though, is not complete if only point sources are identified, monitored, and controlled. A very large portion of our national water quality problems can be traced to such pollutants as sediment, nitrates, and phosphates. These pollutants, and others, are present in the runoff from soil surfaces, tile drainage systems, and streets and yards. Because the runoff from land surfaces generally does not enter the stream or river at one point (or even at the same time), it is termed non-point source pollution. Since it would not be technically or economically feasible to install enough monitoring equipment along a stream to monitor all incoming non-point source pollution, the next best (and only feasible) method of determining the impact of this runoff is to simulate the processes involved with a computer. Not only does this approach lend itself to the research phase of non-point source pollution studies, but it also is a very powerful tool that can be used in the planning and economic analysis phases of these same studies.

At the present time, there are two basic schools of thought or approaches to modeling hydrologic processes and the resulting runoff. The more widely used and publicized concept is the "lumped parameter" approach to modeling. The newer and more complex concept is the "distributed parameter" approach.

In the "lumped parameter" approach, the watershed is treated as a unit. The varying hydrologic responses of the different areas within the watershed are "lumped" into several parameters which describe the watershed response as a whole. Such widely known models as the Stanford Watershed Model(s) and the USDAHL-74 are examples of the "lumped parameter" approach (1,2). This type of model has several strengths.

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It is a much cheaper model to run and can simulate long, continuous records (when calibrated and verified correctly). It is also somewhat easier to set up the descriptive data file for the simulation runs. The "lumped parameter" approach has several weaknesses, though. In order to simulate even small changes in land use within the watershed, the parameters describing the watershed characteristics must be totally recalculated. The output of the model usually can only be collected at a specific point (generally a gaging station, etc.). Due to the "lumped" nature of the hydrologic parameters, very little physical significance exists in the simulation, and, as a result, sediment production, deposition, and transport can only be handled on a statistical or stochastic basis. Finally, a rather extensive data base is required in order to calibrate and verify the model.

The "distributed parameter" approach involves dividing the watershed into areas small enough to be considered uniform (soil type, slope, crop, etc.). The small areas or elements are modeled separately (using flow from upstream or uphill elements as inputs along with rainfall) and the outputs are routed through the watershed. The strengths of this approach are several. The actual processes occurring at a specific point in the watershed are being simulated. The output from the model can be collected at any point or many points in the watershed. Thirdly, although the data file necessary for simulation is rather complex, it is easily and quickly changed to reflect management or cropping changes. Finally, the sedimentation process can be described much more precisely. Two weaknesses are inherent in this model. First, it requires very large amounts or processor time and computer core to run. It is not capable of simulating long periods of record economically (thus it is limited to event or single storm simulations). Secondly, it requires more data for its descriptive data file (watershed description).

This paper will discuss the steps involved in organizing and implementing a computerized model of an agricultural watershed for the purpose of studying the effects of land use and management on water quality. The concepts behind the model and the major operational equations are presented in a concise form.

CONCEPTUAL DESIGN OF THE MODEL

The need for a computer model of agricultural runoff for use in prediction and management practice optimization was realized at the outset of the Black Creek Study (3). However, certain portions of the modeling philosophy have changed as the project investigators have become more familiar with the processes that govern runoff, drainage, and sedimentation. In order to accurately describe the processes involved in agricultural runoff, one must be able to select an area that is small enough so that most of the factors influencing the processes of water and sediment movement, infiltration, and nutrient movement can be considered to be uniform. For this reason, a distributed parameter modeling approach was chosen for this study.

There are several levels of descriptive parameters within the model. First, there are watershed-level descriptive parameters. These include the interception parameters, channel descriptions, antecedent moisture conditions, and control depth for infiltration. Next, there are elemental descriptive parameters. They include the element's location within the watershed, the magnitude and direction of slope, the element's soil type, the crop being grown, the current management practices, whether or not the element is a stream element, and whether or not the element is tile drained. Finally, there are descriptive parameters based on combinations of the above parameters. The infiltration, soil roughness, and sedimentation parameters are based on combinations of the soil type, crop, and management practice within an element.

The element used in this model is a square-shaped area that is 330 feet on a side. This means that the element is exactly 2.5 acres or approximately 1 hectare in size. The topographic information (direction and magnitude of steepest slope) is obtained from USGS 7.5 minute quadrangles that have been photographically enlarged to a scale of 16 inches to the mile (1:3960) and then have been partitioned off using a 1 inch grid pattern. Likewise, the field boundaries and soil types are taken from aerial photographs that have been similarily enlarged and divided into the same grid pattern. The model then divides the flow off of an element into its horizontal and vertical components (with respect to the map) and sends this output to the receiving element(s). No flow is routed to diagonally located elements.

The inputs to an element can consist of rainfall, overland flow from uphill elements, channel flow from upstream elements, and subsurface drainage or tile flow (channel elements only). The outputs from an element consist of a depth of flow (either channel or overland), a subsurface drainage rate, and a rate of sediment movement (the lesser of total detachment or transport).

In order to accomplish the complex task of routing the overland, channel, and subsurface drainage flows and to set up the elemental data files, a separate program was written in order to set up all of the data files necessary for the simulation. This was also necessitated due to the fact that the combination of an initialization and simulation program took up more computer core than the Purdue Computer Center would allocate for a single program.

The simulation program uses the data file (common blocks) set up by the initialization program and stored for this purpose. The simulation consists of adding the rainfall for a specified (GASP IV dependent) period of time and routing the resulting runoff and subsurface flow throughout the watershed in a sequential manner (upper left to lower right). The rainfall intensity and overland flow rates are used to determine the amount of detachment and transport of sediment within each element. The washload from the watershed is considered to be totally transported by the stream flow. Subsurface drainage uses the same routing as surface drainage for simplicity. The normal output of the model describes the flow and sediment concentration with respect to time that occurs at the watershed's outlet element. However, as stated earlier, the output from any element(s) can be collected.

OPERATIONAL EQUATIONS

There are two controlling equations behind this particular distributed parameter modeling approach. Their simultaneous solution yields the depth of overland flow and thus, the surface runoff rate.

The first controlling equation is the Continuity Equation,

$$\frac{dS}{dt} = I - O \tag{1}$$

where : S = storage (area times depth).
t = time,
I = inflow rate to an element,
O = outflow rate from an element.

When both sides of eq. (1) are divided by the element's area, eq. (1) becomes,

$$\frac{dy}{dt} = \frac{(I - O)}{\text{area}} \tag{2}$$

where : y = average depth of water in the element.

The second primary equation is the well known Manning's equation,

$$Q = V \cdot A = \frac{1.486}{n} \cdot R^{.667} \cdot s^{.5} \cdot A \tag{3}$$

where : Q = flow rate,
V = velocity of flow,
A = flow area,
n = Manning's coefficient of roughness,
R = hydraulic radius (A/wetted perimeter),
s = slope.

For wide flow areas, R is approximately equal to the depth of flow, y, and A is equal to y times the width of the element. Thus, eq. (3) can be rewritten,

$$Q = V \cdot A = \frac{1.486}{n} \cdot y^{1.667} \cdot s^{.5} \cdot DX \tag{4}$$

where : DX = width of the element.

The Q in eq. (4) is equal to O in eqs. (1) and (2). Thus, by combining eqs. (2) and (4) and integrating the combination, the depth of flow, y, can be found.

In addition to eqns. (2) and (4), a modified form of H. N. Holtan's infiltration equation is used to account for the water infiltrated during an event and the water that eventually drains to the water table (4,5). The difference in this approach and most others is that Holtan's form uses the water content of the soil (not time) as the independent variable in determining the infiltration rate of a soil layer. The modified equation is,

$$f = fc + A\left(\frac{S - F}{Tp}\right)^{p} \tag{5}$$

where : f = the infiltration capacity (rate),
fc = steady state infiltration rate,
A = maximum potential infiltration rate (above fc),
S = storage potential of a soil within the control zone

F = total volume of water infiltrated,
Tp = total porosity of the control zone layer,
P = a coefficient.

The drainage of water out of the control zone (the water going toward the water table) is determined by the following equation,

$$DR = fc \cdot \left(1 - \frac{PIV}{GWC}\right)^C \qquad (6)$$

where : DR = drainage rate out of the control zone to either the water table or to tile drainage,
PIV = unsaturated pore volume,
GWC = maximum volume of gravitational water,
C = a drainage exponent.

This equation is used to determine the tile drainage rates from elements that have been identified as being tile drained.

Equations (2), (4), (5), and (6) were the basis of a distributed parameter, hydrologic runoff model developed by L. F. Huggins in 1966 (5). That model used a fixed time step and finite differences approach for solving for the overland flow from each element.

The present model is designed to simulate the hydrologic processes that the original model did as well as those of tile drainage, channel or stream flow, and sedimentation. There is, however, a fundamental difference in the operation of the original model and the present model. The present model is written in the GASP IV Simulation Language format. GASP IV is a Fortran IV based, discrete-continuous simulation vehicle. It uses a Runge-Kutta-England integration algorithm with a variable time step for solving differential equations (6).

The tile drainage rates are calculated using eq. (6), when an element has been defined as having tile drainage. Otherwise, no subsurface drainage is assumed to occur.

Some of the elements within a watershed contain channel elements. These elements, then, have overland and channel flow within them. It is necessary, therefore, to be able to describe both the overland and channel flow characteristics of these elements. Also, if there are any tile outlets, this additional inflow must be considered when calculating the element's outflow.

Sediment production and transport are handled in a three-part manner. The equations are adaptations of the Foster-Meyer equations (7), which were modified by Curtis (8).

First, the amount of sediment produced by rainfall impact during a particular time interval is determined by the following equation,

$$GR = CDR \cdot KDR \cdot I^2 \cdot Area \cdot C1 \qquad (7)$$

where : GR = rate of sediment detachment by rainfall impact within an element,
CDR = cropping and management factor (USLE) for rainfall impact for a particular soil,

KDR = erosivity index (USLE) of a particular soil due to rainfall impact,
Area = area of element,
C1 = constant.

Next, the sediment produced by overland flow is determined for the same time interval,

$$GF = CDF \cdot KDF \cdot S \cdot Q \cdot DX \cdot C2 \qquad (8)$$

where : GF = rate of sediment detachment by overland flow within an element,
CDF= Cropping and management factor (USLE) for overland flow on a particular soil,
KDF= erosivity index (USLE) of a particular soil due to overland flow,
S = slope,
Q = outflow from element,
DX = width of the element,
C2 = constant.

Finally, the sediment transport rate due to flow (rainfall splash transport is neglected) is computed from the following equation,

$$TF = CTF \cdot KTF \cdot S^{1.667} \cdot \left(\frac{Q}{DX}\right)^{1.667} \cdot DX \cdot C3 \qquad (90$$

where : TF = sediment transport rate for an element,
CTF = management factor relating to transport,
KTF = transport factor related to particle size distribution and soil condition,
C3 = constant.

The constants C1, C2, and C3 are determined from a regression analysis of constants used to produce simulation output that adequately described rainulator runs in the Black Creek Study area for the soils and other factors in the target watersheds.

PRESENT STATUS OF THE MODEL

The model is presently being used in a slightly modified form to predict the runoff and sediment production on a plot basis for the various rainulator runs on the Black Creek soils. When the output of these simulations is sufficiently close to the observed data, the coefficients C1, C2, and C3, that were used in the sedimentation portion, are saved. When simulations of all of the major soil types are complete, the coefficients will be averaged and assumed uniform from then on for all soils.

The descriptive data files for both of the target sub-watersheds in the Black Creek watershed have been completed. The cropping information and management factors will be those employed in 1976, since there is much more information for this year. However, should problems arise from this approach, there is sufficient data from previous years to generate a fairly complete data file for either 1974 or 1975.

The model has the capability of accepting input data in either English or Metric units. Likewise, the output of the simulation can be specified in either English or Metric units. Both tabular and graphical outputs are provided.

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SUMMARY
by
Carl D. Wilson

A summary of all the papers presented at the seminar on "Best Management Practices for Nonpoint Source Pollution Control" is here compiled as a brief overview of the two day conference. The meeting was held November 16 and 17, 1976 at the Ramada-O'Hara Inn in Rosemont, Illinois. Thirty five presentations were given.

The major objective of this seminar was to present data and information collected from four Section 108 demonstration projects on nonpoint source activities to Section 208 planners and implementing agencies.

The following summaries were extracted from the papers presented.

CALL TO ORDER — Ralph G. Christensen

Under P.L. 92-500, Section 108 (a) provides for grants to support any State, political subdivision, interstate agency, or other public agency, or combination thereof, to carry out one or more projects to demonstrate new methods and techniques and to develop preliminary plans for the elimination or control of pollution within all or any part of the watersheds of the Great Lakes. Such projects shall demonstrate the engineering and economic feasibility and practicality of removal of pollutants and prevention of any polluting matter from entering into the Great Lakes in the future and other reduction and remedial techniques which will contribute substantially to effective and practical methods of water pollution prevention, reduction, or elimination. This program requires a grantee to provide a minimum of a 25% matching contribution to the total cost to the project.

Congress authorized to be appropriated $20,000,000 to carry out the provisions of this program. To date, there have been nine grants awarded under this section of the Act, four of which address the non-point source pollution problem.

WELCOME AND INTRODUCTION

George R. Alexander, Jr.

We, in the Environmental Protection Agency, hope to share some practical, social, and technical information derived from demonstration projects funded from Section 108 of Public Law 92-500.

The agenda for this conference provides an overview of the nonpoint source pollution control mandate given to the U.S. EPA through Public Law 92-500. Among several sections of P.L. 92-500 which address the subject of nonpoint source pollution are sections 208, 303, 304, and 305. In addition to these sections of the Act, Sections 108, 104 and 105 provide for research and demonstration grants which can also address the nonpoint pollution problems.

Nonpoint source pollution is recognized internationally as a problem and is being addressed in the Great Lakes under the U.S. - Canada Great Lakes Water Quality Agreement.

As a result of State and local interest, three demonstration projects have been implemented under Section 108 of P.L. 92-500. These projects will be reported on today by either the grantee project directors and/or their principal investigators.

U.S. EPA OVERVIEW OF SECTION 208 PLANNING

Joseph A. Krivak

There is a message that EPA needs to tell. To let the planners and the decision makers know what is expected before the process is completed not after the plan is delivered. Frankly, I harbor a skepticism about planning -- one born from experience. And also reaffirmed within the last week by a review of the first two 208 plans which have been completed. We have received preliminary reports, two of the initial fourteen. The brief review made, strengthened my belief about the kind of message EPA should put forward to State and Area 208 at this point in the planing process. It is not one of technical data collection and analysis -- by and large, I think that is being done. If anything it may be that we are spending too much time and money on that part of our task. My message instead focuses on our need to get tangible results from the 208 planning process.

The first principle I would like to share my thoughts on is: "Don't spend too much time concerning yourself about how planning is conducted, but worry a great deal about whether it works."

The second principle is to plan sufficiently to produce specific targets, then quit.

The third principle is: insist that the plans result in a commitment to specificed outputs for accomplishment.

The final principle I would set forth is not for the planners but for the decision makers, (the people who hired the planners to get the job done) you have a major responsibility in seeing that the proper goals and objectives are set. In a nutshell, that's the simple basic management guidance that EPA offers you.

NACD View of Section 208

William J. Horvath

National Association of Conservation Districts has seven concerns for the 208 planning process. 1) That the plan have local involvement in its development including conservation districts. 2) That the plan be implementable -- NACD feels this requires the practical approach we have utilized in the district movement. 3) That a vigorous educational program be undertaken with landowners and others to gain acceptance by those who must implement the plan and those landowners affected. 4) That cost-sharing be available for application of BMP's. 5) That adequate funding be made available for securing the necessary technical assistance for applying BMP's. 6) That a continuing research program be undertaken to provide the necessary information to determine the effects of BMP's on water quality. 7) That conservation districts have a major responsibility as a designated agency for plan implementation, and that state soil conservation agencies provide the necessary coordination of that effort.

EXTENSION SERVICE VIEW OF SECTION 208 PLANNING

E. P. Christmas

The Smith-Lever Act of 1914 was the third of three major Public Laws which brought about the development of the Land-Grant College with its agricultural research and extension education activities in the United States. This act provided for the formation and support of the agricultural extension services at the land grant institutions across the country for the purpose of disseminating useful and practical information in agriculture and home economics.

In summary, the key to the success of Extension has been its unique structure as a partnership of the Land-Grant Universities, Federal, State and County governments, with strong guidance from those it serves in the establishment of program priorities. The system has survived because of its objectivity and ability to use research based facts and logical relationships to solve clientele problems.

The role of the Cooperative Extension Service in the 208 Planning Process involves two areas of activity; first, an educational program to inform the agricultural community of the 208 Planning process and secondly, to acquaint agricultural procedures with alternative "best management practices" and their application.

USDA - SCS VIEWS ON 208 PLANNING

Cletus J. Gillman

USDA and SCS both can be classed as strong and willing advocates of the objectives of the Federal Water

Pollution Control Act, particularly the control of nonpoint source pollution under section 208.

To summarize, we believe that improvements in rural water quality will come about primarily from control of nonpoint sources of pollution. This is part of our agency's established mission -- it is our basic work. We have all the authorities necessary -- though short on people and money -- to carry out this essential work. We strongly support a cooperative effort to get the job done. I'm confident that we will change our operations to the degree needed to respond to present and future needs. We in USDA and in SCS stand ready to assist.

A STATE VIEW OF STATE WATER QUALITY MANAGEMENT PLANNING

Rex E Jones

To accomplish control of nonpoint sources of water pollution we must insert a high degree of common sense and reasonableness into the program. This leads into the utilization of best management practices in the solution of our problems. Best management practices will be determined by technical experts in their respective fields. For agriculture, the Soil Conservation Service is a likely candidate to be heavily involved in the determination of potential best management practices to be used in different parts of the country. We must look to best management practices being applied on a case-by-case basis depending upon the individual farm management practices and geographical and hydrologic conditions.

To produce and maintain an effective and meaningful water quality management plan on a statewide basis we must get the program close to the Governor's office.

A very important requirement of this plan is that it be implementable. To me that means acceptable by the people. The easiest way to make sure the people accept the plan is to have the people deeply involved in the development of it. This water quality management plan is not some agency's plan, but it is the people's plan.

If we want an acceptable nonpoint source control plan it will be necessary to make technical assistance available to the landowner. This involves the cooperative approach I spoke of earlier. Another important aspect is the financial feasibility and assistance that must be provided to the landowner. The farmer does not have direct control of the price of his product. There must be some financial assistance on best management practices if we want an acceptable program by the "agricultural community." If you have a knowledge of agriculture, I believe you would think this a reasonable.

It is my opinion that the State's role should be one of strong leadership. Our objective in the Planning Section is to develop and maintain water pollution abatement programs that are effective and meaningful to the people of our State. To accomplish this the State must do certain things. We must provide equity on a statewide basis. The programs must be fair and equal to all parts of our State. The State must also provide consistency between designated agencies and entire planning process. The State should provide guidance to the designated agencies to provide for consistency and equity. A fourth area of responsibility for the State is one of stimulating cooperation between local, regional, state, and Federal agencies. We are all working toward the same goal, hopefully, let's not fight each other. Each level of government has its responsibilities, these should be delineated and agreed upon by all parties involved. The State should lend support to educational programs to tell the story of what we are trying to accomplish and why. It is the responsibility of the State to integrate the designated and non-designated portions of the State to form the Statewide Water Quality Management Plan by November 1, 1978. Another important factor in this planning process is the continuous planning provision which makes the plan much more workable for future application.

I would say one of the keys to making the program successful will be the involvement of the people in the process before the alternatives are developed and the decisions are made. The people of each State must decide what kind of program they want and then support that program as a team. We must be a team.

A COUNTY VIEW OF SECTION 208 PLANNING

Reuben Schmahl

There is today a good segment of our people that have a firm determination to clean up our air and water and strive to halt, to a greater degree, abuse of our lands and to preserve our many natural resources. They have a conviction that we have not moved fast enough in dealing with those problem areas that affect our environment which include erosion prevention and pollution controls. Their great concern is whether existing programs need to be reviewed, amended and refined to improve their degree of effectiveness in reduction of environmental damages.

This sudden explosion of interest on the part of our public has brought about the creation of our Environmental Protection Agency which was established to deal with almost every conceivable aspect of the control and regulation of water pollution and improvement of water quality. Our nation has embarked seemingly on somewhat of a crash campaign against air and water pollution.

As soil stewards, we have a tremendous task confronting us to overcome individual and group resistance to any regulartory or even suggestive measures to correct water pollution and to implement good soil practices. The very vocal and organized resistance to our highway improvement programs can be an example. SWCD boards have authority and a responsibility to conduct programs to control erosion of lands and sedimentation of our waters. Conservation districts have good organization and utilize effectively an extensive network of cooperative arrangements with federal and state agencies in planning, research, education, cost sharing and technical assistance. This arrangement has provided a very workable method for cooperatively establishing conservation practices on our land and has been used for about the past forty years.

SOUTH EAST WISCONSIN REGIONAL PLANNING COMMISSION (SEWRPC) VIEW OF SECTION 208 PLANNING

Lyman F. Wible

Our agency was designated as the area wide water quality planning agency in December of 1974 and accordingly we will conclude our 208 project period in December of 1977. The Regional Planning Commission itself is composed of three representatives from each of the seven counties in and around the Milwaukee metropolitan area. It was organized in 1960 as a result of wide-ranging public discussions and debate initiated in 1948. It is especially interesting today to note the twelve years required to sucessfully determine the appropriate planning boundries for the Southeastern Wisconsin Region,as compared to the time available for designation of 208 agencies.

In summary, the Commission views 208 as an element of the comprehensive physical plan for this Region; as a complementing program update, refine, and extend our previous water resources planning efforts, as a challenge to be met in integrating diverse planning programs; as dangerously brief in its plan development and implementation emphasis; and as an exciting experience in analyzing all of the factors affecting water quality and in developing the public support necessary to abate pollution.

It can be stated, by misquoting an old saying that, "The 208 Program offers incredible opportunities to a regional planning commission -- but they come in disguise as insoluble problems." In solving those problems we feel that highly useful information can be developed for sound water quality management decisions in southeastern Wisconsin.

CONGRESS PERCEPTION OF SECTION 208 PLANNING

Congressman J. Edward Roush

The legislative history of Section 208 is discussed as an atempt to resolve concerns over area planning and unique water quality problems for diverse areas within the United States. Concern is expressed that implementation of Section 208 planning has moved slower than envisioned by the congress with the adoption of Public Law 92-500. It is predicted that pollution from non-point sources can overwhelm progress made under the municipal construction grants and the pollution elimination discharge permit system. Confidence is expressed that the approach of Section 208, involving federal, state and local cooperation has a good chance of success.

THE WASHINGTON COUNTY PROJECT - AN OVERVIEW

T. C. Daniel

The primary objective of the Washington County Project is to demonstrate the effectiveness of land treatment measures in improving water quality, and to devise the necessary institutional arrangements required for the preparation, acceptance and implementation of a sediment control ordinance or other management program applicable to incorporated and unincorporated areas on a county-wide basis.

The conceptualization of the project, the participation and involvement of appropriate interest groups and the development of project objectives is reviewed. Each objective is discussed with emphasis on strategies for implementation and accomplishments to date.

Development of the Washington County Project began in April of 1973 as a result of the Governor's Conference on Sediment and Erosion Control held at Madison, Wisconsin.

EROSION-SEDIMENT CONTROL PROJECT WESTERN LAKE SUPERIOR BASIN

Stephen C. Andrews

The Red Clay Project is a research and demonstration project funded by the U. S. Environmental Protection Agency under Section 108 of the 1972 Amendments to the Federal Water Quality Act (PL 92-500). Section 108 provides funds for projects in the Great Lakes Basin for the collection of data to be used as a basis for planning and implementing non-point source pollution control programs to help improve water quality.

Ashland County was selected to demonstrate shoreline protective devices including rip-raping and selected configurations of longard tubes.

Early surveys of four potential sites indicated that the Indian Cemetery site on Madeline Island would be an appropriate location for rip-raping. In addition to providing demonstration capability, it also will protect a valuable archeological resource. Madign beach, about 15 miles east of the City of Ashland was chosen for the longard tub research and demonstration area. This beach has many high erodible clay bluffs which need stabilization. The primary problem is one of waves eating out the tow of these slopes. It is felt that Longard tubes in seawall and grain configurations may be useful in stabilizing the bluffs.

At the time of this report, permits have been secured from the Wisconsin Department of Natural Resources and the Army Corps of Engineers. It is expected that construction will commence early in the spring of 1977.

BLACK CREEK PROJECT-OVERVIEW

Ellis McFadden

The Black Creek Sediment Control Study, an Evironmental Protection Agency funded project to determine the environmental impact of land use on water quality is finishing its fourth year of activities. The project, which is directed by the Allen County Soil and Water Conservation District, is an attempt to determine the role that agricultural pollutants play in the degredation of water quality in the Maumee River Basin and ultimately in Lake Erie.

The Black Creek prject was designed and developed by a consortium of the Environmental Protection Agency, the Soil Conservation Service of the United States Department of Agriculture, Purdue University, and the Allen County District. It is a response to allegations, first brought to the attention of Allen County residents at a conference on the future of the Maumee River sponsored by Representative J. Edward Roush in January of 1972.

At the conference, sediments and related pollutants were named as major contributors to the degredation of water quality in Lake Erie. It was further suggested that agricultural operations significantly increased the amount of sediment and sediment related pollutants.

The Black Creek Sediment Study, funded by a grant of nearly two million dollars is an attempt to discover the role that agricultural operations play in the pollution of the Maumee River and how that role can be diminished through the application of significant land treatment practices.

The project represents a multi-agency, multi-discipline approach to the total problem of non-point source pollution. It involves demonstration, through a problem of accelerated land treatment with the assistance of the Soil Conservation Service, applied research by Purdue University, administration by the Allen County Soil and Water Conservation District, and cooperation from a variety of state, federal and local agencies, as well as the private landowners in the study area.

CHALLENGE OF SECTION 208 PLANNING

James Morrison

Awareness of the problem of non-point source pollution is seen as a traditional process of environmental consciousness raising. Agricultural pollution is seen as different from other types of pollution because control involves not only economics but the availability of a basic resource. Combinations of impacts on both the profitability of agricultural operations and the productivity of agricultural land are discussed. It is noted that Congress inserted the words "to the extent feasible" in its adoption of Section 208 concerning agricultural pollution. A definition of "feasible" is cited as a major challenge to Section 208 planners.

PUBLIC PARTICIPATION IN LAND USE PLANNING AND MANAGEMENT

F. W. Madison

The goal of the Washington County Project is to develop and institutionalize a sediment control mechanism for Washington County, Wisconsin. To accomplish this, technical information generated by physical scientists from an extensive monitoring network as well as legal and institutional alternatives developed by social scientists must be transferred to citizens and local decision makers to create an awareness of and support for those legal and institutional changes needed to control nonpoint source pollution. It should be made clear that the Washington County Project is operating at two levels: one, of course, involves the development of a specific sediment control mechanism or mechanisms for Washington County while the other involves the development of methodologies, strategies for implementation or whatever that can be generalized and utilized in other parts of Wisconsin, of the Great Lakes Basin and perhaps of the entire country.

Strategies for information dissemination and public participation in the Washington County Project were identified by project staff working with local citizens and county personnel. Initially, they involved two important assumptions. First, it was agreed that the general level of understanding and awareness of nonpoint source pollution was limited and thus, that early informational effort would have to be directed toward simply pointing out the problem and explaining some of the more basic--and technically well understood--processes and problems. Secondly, it was recognized that nonpoint source pollution is basically a people problem. Much of the problem can--and probably will--be solved if people are made aware of the causes and dimensions of the problem and of the fact that many of the things they do in everyday life can affect the problem. In urban areas, fertilizers and pesticides improperly applied to lawns and gardens are a problem as are grass clippings and leaves dumped in gutters. On farms, cattle watering in streams and manure spread on steep, frozen ground are significant nonpoint source pollution problems.

LAND MANAGEMENT INSTITUTIONAL DESIGN FOR WATER QUALITY OBJECTIVES

Carlisle P.Runge

The problem of nonpoint source water pollution control is at once a problem of the interface of land use and water quality problems and a problem of federalism -- the carrying out of policy in the intergovernmental framework. The purpose of this paper is to present the issue of nonpoint source pollution control in its historical/institutional contexts and to suggest principles of institutional design which respond to this context and which build on it, with emphasis on institutional patterns in Wisconsin and the experience of the Washington County Project.

The set of nonpoint source problems should be seen, institutionally, as the combination of developments in water resources policy and land management. These two issues have developed along separate "tracks" through the history of the United States. Each requires examination in terms of institutions and authority at federal, state and local levels in order to establish a framework for approaching the problems of land related pollution control.

In conclusion these general principles of institutional design and observations suggest a substantial local role in program implementation based on state guidelines and standards, which, in turn, carry out federal policy; all should be seen as an institutional arrangement which is conditioned by the historical experience of the separate approaches to water resources and land management in the United States. They are consistant with Constitutional precepts and legal history which limit the federal role in private land management in favor of authority reserved for the states and conducted locally in most instances. They also recognize the degree of federal influence in water resources matters which is a policy of long standing. The administrative experience of numerous institutions at the several levels of government is incorporated into such possible approach. These observations include an appreciation of the social traditions and values which are associated with the holders of land in America. Finally, these considerations have a bearing on the degree of public management of private lands, the levels of government and the issues of private-public cooperation, responsibility and allocation of costs and expected benefits.

PLANNING DIFFUSE POLLUTION CONTROL

Robert Schneider

A framework was developed formalizing the evaluation of costs and benefits of nonpoint pollution control and making explicit the informational requirements necessary to the analysis. Its usefulness in designing discriminating legislation was considered. Such a scheme should prove useful in (a) developing a system of classification useful for efficient nonpoint pollution control, and (b) determining areas of major research priority to aid in the development of nonpoint pollutant control.

BEST MANAGEMENT AND TREATMENT PRACTICES FOR WATER QUALITY

Gregory L. Woods

In evaluating a farm, each field or farming unit is analyzed for basic soil loss using the universal soil loss equation. The equation, our only tool for estimating soil loss is shown as:

A = RKLSPC, where
A = is the computed average annual
soil loss per unit area
R = rainfall factor
K = soil erodibility factor
L = slope steepness factor
S = slope steepness factor
C = cropping management factor
P = is the erosion control practice factor

It is readily seen that of the six factors only three can be significantly changed or altered by man. Rainfall, soil erodibility, and slope steepness always remains static.

IMPLEMENTING AND MONITORING CONSERVATION PLANS

Thomas D. McCain

Reviewing land treatment accomplishments in the Black Creek Sediment Study Project as we complete this fourth construction season, reflects interesting changes in attitudes of technicians, planners and the people of the watershed. The current emphasis on major management objectives has been a modification of original ideas. When the initial work plan was assembled four (4) years ago there was conserted effort by the Allen SWCD, SCS and Purdue University people to accumulate, analyze and evaluate all the resource data available for Black Creek. Even looking back to the initial review of the Maumee Basin we set out to find a difficult situation where some type of "demonstrational" applied land treatment program could accomplish the desired objectives. Black Creek was selected as the most typical mini-basin.

AN INSTITUTIONAL APPROACH TO IMPLEMENTING BEST MANAGEMENT PRACTICES

James E. Lake

The Black Creek Study, one of three section 108 projects funded by Region V of the United States Environmental Protection Agency is presently finishing its fourth year of activity. The project is scheduled to study is Environmental Impact of Land Use on Water Quality, however, it is more commonly referred to as the "Black Creek Study." The Allen County Soil and Water Conservation District, Allen County Indiana, accepted the 1.8 million dollar grant from EPA in October of 1972.

The main purpose of the study is to attempt to determine the role that agricultural pollutants play in the degredation of water quality in the Maumee River Basin and ultimately Lake Erie.

The project was designed and developed by a consortium of the U.S. Environmental Protection Agency, the U.S. Soil Conservation Service, Purdue Univeristy, the office of U.S. Congressman J. Edward Roush, Allen County Soil and Water Conservation District, and Allen County Surveyor's Office.

First, I think it is significant that we were able to sign cooperative agreements with 95% of the landowners in the watershed. A cooperative agreement simply means that the landowners we contacted were interested enough in knowing what was available through the project that we are able to sign cooperative agreements with 95% of the landowners in the watershed. A cooperative agreement simply means that the landowners we contacted were interested enough in knowing what was available through the project that they signed an agreement asking for the technical assistance to survey and design measures that could be applied on their land. Only 5% of the landowners in the watershed were unwilling to venture this far. Over 80% of the landowners in the watershed have signed a legal contract with the district for the application of land treatment practices on their farms. The contracts simply state that the landowners will install the needed erosion control practices as outlined on their contract and that the district will supply the cost-share incentives and technical assistance as stipulated on the contract. Cost-share incentives on the practices averaged 70% for all the practices applied. At the end of four years of application a little over 57% of the watershed has been adequately treated with erosion control measures. The district has spent approximately four hundred and forty-four thousand dollars as of September 30, 1976 for payment to landowners applying practices.

In evaluating the 31 practices our district can only justify the expenditures on less than ten practices relative to the goals of erosion control and improved water quality.

From our experience on the project to date, of the thirty-one practices originally outlined in the work plan the district would recommend these best management practices: The first best management practice which is very significant to Black Creek and many areas of the country is Conservation Tillage and within conservation tillage you gain proper crop residue management. The second would be Parallel Tile Outlet Terraces. In order for terraces to be installed other practices must be incorporated in the terrace plan and are really required by the terrace system; these would be conservation cropping system (crop rotation), title drainage and contour farming. The third practice is Pasture and Hayland Planting. Some areas are critical enough that they need to be removed from crop land and placed in permanent pasture. Another "BMP" would be Animal Waste Holding Ponds and Tanks. Included in this practice area would be any management facility which would control runoff of animal waste into public waterways. Other best management practices would include: Grade Stabilization Structures, Grass Waterways, and Sediment Control Basins where needed. The last category of best management practice would be those practices related to the stream, which are: Streambank Protection, Streamchannel Stabilization, and Field Border establishment. The other practices listed in the original work plan can be considered on a complete conservation plan for a land unit but we feel should not be assited with public dollars because there are not sufficient public benefits to justify public funding.

It is not feasible to select best management practices at any level higher than the local SWCD, simply because the practices vary with location.

In all reality, however, the application of best management practices to the level necessary for waste quality improvement will not be accomplished on a totally voluntary program. Enforcement will be needed on a small percentage of the landowners. In order to be sure that best management practices are installed properly and at the amount necessary for erosion control in the county it will be necessary for the state agency to provide enforcement when requested by the district. It would be the district's obligation however to submit a written request to the state agency for its assistance in seeing that enforcement is properly carried out when needed. This, however, would not be direct enforcement but would come about as the result of the district informing the landowner that if he does not cooperate with the district and install the needed practices the state will come down on him with enforcement measures such as fines, etc. Using this approach there will probably be very few cases where the district will be unable to obtain cooperation for proper application of practices. However, I would estimate that there are approximately five percent of the landowners who will not react to anything less than enforcement.

If all of this is to come about, and in reality be a implementable program, the first thing that must be recognized is the Soil and Water Conservation Districts do need to hire professional district representatives to assist them with management. By this I mean the local soil and water conservation district supervisors must have an executive secretary who is a professional, qualified to manage their programs. This needs to be someone who is in the district office day by day and knows what is happening and can inform the supervisors of the local needs and problems.

Soil and Water Conservation Districts throughout the country want to be part of planning for non-point pollution control. Anyone involved in 208 programs should definitely consider getting the local SWCD involved if they have not already done so. The project also points out that soil and water conservation districts are going to need to make some changes to meet the challenges of non-point pollution control in the future.

SOCIAL FACTORS THAT INFLUENCE PARTICIPATION IN SOIL CONSERVATION: BLACK CREEK PROJECT

David L. Taylor
William L. Miller

One of the most important tasks that faces any program designed to influence or alter the social behavior of a group of people is how to attain the cooperation and participation of those people. This is absolutely necessary if the project is going to achieve its goals without coercion and/or creating in unfavorable image amoung those persons.

In the Black Creek Project, farmers are being encouraged to adopt agricultural management practices on their farms which benefit society by reducing the runoff of sediment and nutrients which pollute streams and lakes. To achieve this objective economic incentives have been combined with information designed to encourage the farmer to adopt management practices to reduce runoff. To personnel involved with this project who have worked with the farmers, it has been apparent that the adoption of a particular management practice varies between farmers and groups of farmers in the project area.

The objective or this research is to determine which factors are most important for adoption of the management practices. In addition, it will determine at what stage in the decision making process these factors exert their major influence on the behavior of farmers.

CONSERVATION TILLAGE TRIALS IN PROGRESS IN THE BLACK WATERSHED

Donald R. Griffith
Gary W. Carlisle

Simulated rainfall studies have shown that conservation tillage techniques are quite effective in reducing water runoff, soil loss, and pollutants associated with soil loss. Previous research in Indiana and other Corn Belt states, however, indicated that the various conservation tillage systems are not uniformly adapted in all soil-climate situations.

Factors shown to have major influence on the success of conservation tillage systems are soil drainage, previous crop length of growing season, and soil physical properties.

The first three years of the project fall chiseling with limited secondary tillage in the spring, appeared to be successful with a wide range of soil types and weather conditions.

Specific objectives of the tillage trials, listed below, are aimed at reducing soil erosion in the watershed.

1. To determine which conservation tillage systems are adapted on the primary soil types in the watershed. Adapted, in this case, means that the system can be used by farmers of average managerial ability without risk of significant yield reduction.

2. To have conservation tillage techniques in use by a high percentage of farmers in the watershed.

Weeds not controlled with no-plow were primarily species resistant to herbicides used. These included field bindweed, morning glory and Canadian thistle. The pre-emergency herbicides used were an Aatrex-Bladex-Lasso_Paraquat combination on corn and a Lorox-Lasso-Paraquat combination on soybeans.

Another interesting observation during the growing season is the development of phytophthora root rot disease of soybeans in the Nappanee silt loam trial. It became much more severe in no-till and disk plots than in deep tilled plots, and yields were reduced by 75%.

All three of the conservation tillage demonstrations appear to be successful. The sod-planted corn showed no drouth stress during an early season dry period, while other corn in the same field was showing drouth symptoms. Moisture conserved with no-till sod planting is a prime advantage for this system on well drained soils.

CROP SEQUENCE AND FALL TILLAGE

J. V. Mannering
C. B. Johnson

The Black Creek Watershed, a 4,850 ha sub-watershed of the Maumee River Basin is an area of intensive farming with an estimated 60% of the area devoted to row crop (corn and soybean) culture. The dominant cultural practices used in corn and soybean production within the watershed consists of fall turn plowing, secondary tillage for seedbed preparation in the spring and cultivation for weed control. Although this method of crop production is agronomically sound (except of highly erosive soils), it does leave a large percent of the watershed unprotected and subject to erosion during a large part of the year. Conservation tillage systems have been shown to effectively reduce soil erosion at several locations in the Cornbelt where erosion is a problem. It is important, then, to determine the effectiveness of these conservation tillage systems in reducing the soil erosion and resultant sedimentation problems in the Black Creek Watershed.

These results are still considered to be a preliminary nature and further analyses might alter them slightly. However, several conclusions can be made at this time. This include:

a) Tillage systems performed in the fall have significant effects on the amount of crop residue remaining on the surface in the spring. Surface cover averaged over four locations amounted to 21, 11, 10, and 2% respectively, for the check, disk, chisel and plow treatments following soybeans. Following corn these values were 64, 65, 37, and 4%.

b) There is a strong interaction between crop sequence and tillage system as to their effect on surface cover. When averaged over the four locations surface residue cover in the spring after fall tillage following soybeans was 33, 18, and 33% respectively, of that after from the check, disk and chisel treatments.

c) Soil losses in the spring are much greater following a crop of soybeans than following a crop of corn. Averaged over four location, land following soybeans was found to be 5.2, 7.1, 2.7 and 1.4 times more erosive than land following corn from the check, disk, chisel and plow treatments, respectively. This relationship did not appear to be greatly different on the nearly level lake plain soils or the sloping glacial till soils. It should be mentioned, however, that soil losses across all treatments were much lower on the neraly level sites than on the sloping sites. Another point should be made about thes data. They represent only the most erosive part of the fallow and crop residue periods, not the entire season.

d) Soil losses are inversely related to percent surface cover. Generally, the greater the surface cover, the less the erosion regardless of the crop involved. However, some crops produce more total residue than others and the residue produced decomposes slowly because of high carbon-nitrogen ratios. A good example is corn versus soybeans.

e) Those tillage systems that leave large amounts of crop residues on the surface are effective in significantly reducing soil erosion in the Black Creek Watershed. Particularly effective are check (no till) and disk treatments following corn since large amounts of surface residue still remain in the spring. Fall chiseling following corn although not as effective as the two treatments mentioned above, significantly reduces erosion, compared to plowing. The degree of erosion control is dependent upon the amount of surface cover remaining as well as the roughness of the surface. None of the conservation treatments are as effective following soybeans as following corn because of reduced surface cover. Chiseled soybean land can be particularly erosive following a poor crop and when chisel marks run up and down slopes.

f) Gross field erosion is 3 or more times greater from the sloping soils in the watershed than from the nearly level portions. For this reason, it is still more important to concentrate conservation tillage and other conservation practices in the more erosive areas.

SEDIMENT YIELD FROM AN AGRICULTURAL WATERSHED INTO THE MAUMEE RIVER

E. J. Monke

The annual sediment yield from the Maumee River into Lake Erie averages around 500 kg/ha from the entire Maumee Basin. This sediment, consisting almost entirely of suspended load, may be contributing to the eutrophication process in Lake Erie by acting as the transporting agent for chemicals notably phosphorus.

During 1975, the sediment production from the Black Creek Watershed into the Maumee River averaged about 3900 kg/ha. This rate was substantially higher than the estimated 1000 kg/ha for 1974 and was caused by greater than average rainfall. Also several large storms occurred during May when around 50 percent of the land surface had been just recently tilled. Total phosphorus and nitrogen runoff were 9 and 78 kg/ha, respectively.

Two subwatersheds were studied in particular: One contained 26 percent mostly level and 74-percent rolling topography and was 40-percent in row crops, and the other contained 71-percent mostly level and 29-percent rolling topography and was 63-percent in row crops. The first subwatershed had a sediment yield of 5400 kg/ha as compared to 3500 kg/ha for the latter. Phosphorus yields were about the same for both watersheds even though the sediment yields were substantially different. Higher fertility levels were maintained in the more level subwatershed, however. The nitrogen yield was 67 kg/ha for the first subwatershed as compared to 89 kg/ha for the other. Again the more level subwatershed had higher fertilzer application rates. It is also extensively tile drained. The difference in sediment yield from the two subwatersheds suggests that the more rolling land contributed a large share of the total yield even though the soil surface was better protected (40 vs 63-percent in row crops). The major portion of the soil loss from the more level lands occurred only during the large storm events.

The best management practices for reducing soil erosion in the watershed seem to be those practices which protect the most soil surface over the longest period of time. Any form of minimized tillage and better residue management would fall into this category. A best management practice for substantially reducing the off-site effects of erosion is the temporary storage of runoff. Parallel, tile-outlet terraces (also reduces field soil loss) and small detention reservoirs located near the outlets of tributary drains are examples where the temporary slow-down and storage of runoff waters may allow 90-percent more of the sediments to drop out.

For 1975, the sediment yield from the Black Creek Watershed into the Maumee River was 3900 kg/ha. Major storm events during late May and early June caused about one-half of the total sediment load. Since many drains were overtopped from one particularly intense storm, severe scouring on the nearly level portions of the watershed contributed a normally disproportionate share of the total sediment yield. Even so, the sediment yield from the nearly level portion of the watershed was estimated at only 2400 kg/ha as compared to 6500 kg/ha from the gently rolling portion. Best management practices put into the upper one-third of the watershed on the gently rolling glacial till soils should prove to be the most beneficial of any location in the Black Creek Watershed.

NUTRIENT CONTRIBUTIONS TO THE MAUMEE RIVER

D. W. Nelson
L. E. Sommers
A. D. Bottcher

Total amounts of water, sediment, and nutrients discharged from two subwatersheds of the Black Creek study area during 1975 were determined. In excess of 5000 kg of sediment/ha was transported past the two sampling sites during the year. Quantities of most nutrient forms were similar to those observed in other watershed studies except that the amounts of nitrate N discharged were high (25-34 kg/ha). Most of the total P transported was sediment-bound P, whereas a substantial proportion of the total N in stream water was nitrate. Partitioning the total amounts of sediment and nutrients transported by type of flow indicated that small hydrological events were responsible for most transport, however, large events transported a higher proportion of sediment and sediment nutrients in relation to flow. Amounts of suspended and soluble constituents transported in base flow was low. Surface runoff was the major source of sediment, sediment-bound nutrients, ammonium N, and soluble organic N and transported in the subwatersheds. Significant proportions of nitrate N originated in tile drainage and subsurface drainage water. A substantial proportion of soluble inorganic P was derived from septic tank effluent in one subwatershed containing a large number of houses. Calculation of proportions of N and P added as fertilizer and manure which were recovered as soluble inorganic nutrients in streams indicate that significant losses of added N are occurring in the watershed. Very low losses of added P were observed.

The following conclusions may be drawn from the data presented in this discussion:

1. Sediment and nutrient losses in watershed are not large with the exception of high NO_3-N losses.

2. Greater than 90% of total P transported in watershed is sediment P; only 50-60% of total N transported is sediment N. N movement is more difficult to model than P transport.

3. Transport of sediment and nutrients in the watershed is associated with storm events; less than 10% is transported during base flow. Storms must be well monitored.

4. Sediment content and sediment nutrient concentrations increase markedly during storm events. Concentrations of soluble nutrients usually decrease during large storm events.

5. Surface runoff is the major source of sediment, sediment-bound nutrients, soluble P compounds, and ammonium. Subsurface drainage water is the major source of nitrate. In heavily populated parts of the watershed septic tanks may be a major contributor of inorganic P.

6. Approximately 45% of the N added as fertilizer and manure is recovered in drainage water from the watershed. Only 0.5% of the added P is recovered in drainage water.

SEDIMENT REDUCTION BY STREAMBAN MODIFICATION AND SEDIMENT TRAPS

R. Z. Wheaton and
R. E. Land

Considerable work has gone into the Black Creek watershed in stabilizing channel banks and slopes throughout the area. As reported at the 1975 Seminar the structural and the bank stabilizing practices have generally been very successful. However, continued observations throughout the study has suggested that in some reaches of the channel the bottoms may be continuing to degrade. Also, soil mechanics studies identified several locations where the channel bottoms were potentially unstable. This study showed that the most likely reason for instability was excess channel slope and often a less resistant soil material in the profile near the channel bottom. It is evident that if a channel bottom degrades that eventually even stable banks must become unstable.

The Sediment Pond: on the Virgil Hirsch farm was constructed in the fall of 1973 and filled to overflowing in November of the year. It serves a drainage area of 185 ha (460 acres). The soil types are Hoytville and Nappanee. The land slopes are generally less than one-half percent. With the water level at the crest of the mechanical spillway the water surface area of the pond is just over 2.4 ha (6 acres). The flood storage is 14,000 cu meters (11 acre ft.) with a detention time at flood design of 4-1/2 hours and as estimated flow-through time for one hour.

On May 18,1976 with the assistance of the Soil Conservation Service state geologist cross sectional profiles were run over 30.4 meters (100 ft.). Depth of accumulated sediment was determined across each base line or station. These depths were determined by the use of a recording fathometer and by probing. Sediment deposits were examined for determination of particle size. Sediment samples for laboratory analysis were collected at a later date.

Sediment deposits were found to be very uniform in depth throughout the pond area with an average accumulation of 6 cm (0.2 ft.). Likewise particles size appeared to be very uniform, being primarly in the clay and silt fractions with possibly as small amount of fine sand.

Laboratory analysis of the samples confirmed that the sediment is a silty clay texture. The range of the sample analysis were as follows:

silt	52.1--63.9%
clay	31.9--42.0%
sand	4.2---5.9%

From the depth of the sediment accumulation calculations indicate that in the nearly three year period since construction the sediment pond has accumulated approximately 1880 cu m (2400 cu yd.) of sediment. Assuming a dry weight of 857 kgm per cu meter (55 pounds per cubic foot) this amount to an average of 2.8 tonnes per ha per year (1.2 tons of sediment per acre per year) for each of the three years of the nearly three year period from construction until the survey. However, this figure should not be considered anything more than the averge accumulation for the years 1973-1976.

The Desilting Basin: on the main stem of the Black Creek was constructed in September of 1974 and was first surveyed on July 30, 1975. A second survey was conducted July 7, 1976. Sediment samples have also been collected from this basin for particle size determination.

The first survey covering a period of approximately nine months showed an accumulation of 770 cubic meters (980 cubic yards) of material. The second survey shows an additional accumulation of 416 cu meters (530 cubic yards in approximately a one year additional time. Sediment sample analysis are shown in Table I. This table shows only the percent sand by size fraction and does not include the finer silt and clay fractions. It is only at stations 460 and 461 where less than one-half of the sediment accumlated was in the sand size fraction.

This would indicate that much of the material being trapped by this desilting basin is bed-load. To date no evidence has been seen of additional scour of the channel immediately below the desilting basin. The first 50 meters (150 ft.) of this basin is nearly full of sediment, Figure 5. There is considerable accumulation throughout the basin. If it continues to trap material at the present rate it will have to be cleaned out in a year or two to remain effective.

ENVIRONMENTAL DATA ACQUISTION AND REAL-TIME COMPUTERS

L. F. Huggins
S. J. Mahler

The on-line computer on the Purdue campus is a minicomputer running a general purpose time-sharing operating system. The Black Creek installation is seen by the computer as simply one of several simultaneous users active on the system. The operating program which controls communication with the Black Creek station has four primary responsibilities: (1) assembling the incoming data into suitable files and permanent storage of these files on magnetic disk and/or tape, (2) maintenance of a dynamic file of the instantaneous level of all variables being monitored in the watershed and the operational status of all transducers, (3) providing a preliminary analysis of water stage data in order to issue feedback control commands to operate the water sampling equipment, and (4) detection of storm conditions in the watershed that indicate the need to activate a complete real-time simulation of the hydrologic behavior of the catchment. During a runoff producing storm, a simulation model is activated which combines historical data files describing physical characteristics of the catchment with real-time, dynamically changing data conerning rainfall intensity distribution and stream stage to estimate height and times of peak flows at all points in the drainage network. If the geographical local warrented such action, the computer could be programmed to automatically ALERT responsible authorities in the event of impending dangerous flood levels.

The collection of comprehensive environmental data is an essential requirement for rational planning of non-point pollution control measures and for subsequent enforcement and post-planning evaluation activities. Several examples of such activities underway in the Black Creek Study Area have been described. The dramatic impact of utilizing real-time computers to collect environmental data has been outlined. Proper transducer selection and data network configuration allow existing time-sharing computer systems to serve as real-time systems for most environmental data requirements with no additional hardware of system level software changes. This approach provides the benefit of an on-line computer with no capital outlay beyond those associated with a data logging system of greatly reduced capability. While operating costs will be slightly higher for the real-time system, these extra costs are primarily proportional to the degree of utilization of the on-line features of the system and are therefore subject to cost/benefit consideration and administrative control. Furthermore, many of these associated benefits are sufficient to significantly influence the economic justification of the network of field transducers required for any degree of automation of data collection procedures.

DETERMINANTS OF WATER QUALITY IN THE BLACK CREEK WATERSHED

James R. Karr
Daniel R. Dudley

A series of 120 sample locations have been selected within the Black Creek watershed to sample areas of different stream morphology, land use, vegetation cover, and other factors with the objective of a detailed analysis of relationships between these factors and water quality. The short time since initiation of our expanded effort precludes a detailed analysis. Three major stream conditions are identified during a prolonged dry period in the summer of 1976. These three regions are: 1) base flow area maintained by groundwater, 2) intermittent flow zone downstream from Harlan, and 3) dry stream channels with stagnant pools. Groundwater flow had significantly lower turbidity, phosphorus, and ammonia than downstream stations indicating these materials are accumulated from the Black Creek channel rather than being picked up by surface runoff.

Four major regions of stream were selected for comparisons of water quality throughout the watershed. In general, Driesbach Drain carried the largest volumes of sediment and nutrients while Wertz and Smith-Fry Drains contained the lowest concentrations. The main Black Creek channel below Brush College Road was intermediate. Harlan was a major source of nutrients and suspended solids in the watershed. Considerable find scale variation is evident throughout the watershed and detailed analysis of that variation will be presented in a future report.

A number of channel and tile flow sites were selected for monitoring organic pollution levels in the watershed. In general, highest bacterial counts are associated with Harlan and lowest counts occur in the tributaries such as Wertz and Smith-Fry Drains.

Bacterial counts decline downstream in Black Creek. Counts in the nearby Wann Ditch are below those in Black Creek. A number of surface and tile samples throughout the watershed indicate contamination from domestic sources. Fecal coliform/fecal streptococcus ratios indicate that most contamination is from human wastes. Accumulation of organic pollutants in anaerobic sediments suggests that the capacity of the biota to assimilate these materials is being exceeded.

CULTURALLY INDUCED ACCELERATION OF MASS WASTAGE ON RED CLAY SLOPES LITTLE BALSAM CREEK, DOUGLAS CO., WISCONSIN

J. T. Mengel Jr.
B. E. Brown

GEOLOGY

General Statement

The Little Balsam Creek drainage was selected for investigation in the hope that it was representative, within a limited area, of many of the geologic and engineering conditions in the Nemadji River watershed and other parts of the red clay plain which borders the southwestern side of Lake Superior. Data in this report proves that it is representative of the Douglas County portion of the Superior plain and it is probable that the conclusions reached here are applicable to much of the remainder of the plain in Michigan, Wisconsin, Minnesota.

In Douglas County, Wisconsin the altitude of the Superior plain ranges from about 625 feet above mean sea level along the Lake to about 1100 feet along the South Range, a sand covered highland with a lava bed rock core which is the south boundary of the red clay area (Figure 1). The plain is underlain by glacially derived materials consisting of a thick surface layer of red brown and associated grayish clays and brown sands, which rest on a vaguely stratified clay layer which contains large but variable amounts of silt, sand, gravel, and coarser material. These Quaternary age sediments are underlain, inturn, by red sandstones or black basaltic lava flows of Late Precambrian (Keweenawan) age.

Toe undercutting triggers movement of the bank surface which may extend far up slope and involve piecemeal movement of the entire surface. The depth of the sliding mass rarely exceeds 5-7 feet and does not involve the entire valley, wall, only its surface. Movement is mainly translational downslope rather than rotational into the slope. Small scale rotational slump along shallow arcs is common especially at the toe and the crest of the more active slopes.

Toe protection can probably still help reduce clay loss from some slopes, but in most cases where recent stream downcutting and toe undermining is already advances, such measures will be of little help because such slopes alread contain numerous factures which allow easy water penetration and the slopes lack necessary toe support.

EFFECTS OF RED CLAY TURBIDITY ON THE AQUATIC ENVIRONMENT

W. A. Swenson
L. T. Brooke
P. W. DeVore

Lake Superior is the largest and one of the purest large bodies of fresh water in the world. Turbidity occurring in the extreme southwestern portion represents the only major exception to this characterization. The turbidity results from erosion of glacial-lacustrin red clay deposits laid down by Glacial Lake Duluth which occur in a continuous zone along 75 km of shoreline form Superior to Port Wing, Wisconsin and cover an area approximating 3,600 km^2 (1). Erosion of clay from shoreline bluffs, river basins and resuspension from the lake bottom is associated with periods of onshore wind, spring runoff and precipitation. Clay plumes may extend from a few hundred meters to several kilometers into the lake.

Red clay erosion in the western Lake Superior drainage has reduced the value of the water resource for reaction, navigation and municipal water use. Studies on the effects of turbidity on aquatic life in the lake and the Nemadji River system indicate that fish and benthic invertebrate communities are influenced and exhibit direct behavioral responses to turbidity. Research completed on the lake commnity shows red clay turbidity results in changes in nutrient levels, quality and depth of light penetration and zooplankton and fish distribution. Changes in distribution alter predatorprey interactions. Major differences in community structure were identified between clear and turbid waters.

Preliminary results from an ongoing study of the effects of erosion and erosion control practices in the Nemadji River system suggest existing turbidity and related clay sedimentation have no significant negative effects on macroinvertebrate standing crops on species diversity. The only major changes in species composition are the addition of burrowing mayflies (e.g. *Hexagenia* sp., *Caenis* sp.) when the bottom type is composed primarily of silts and clays. A heavy sand bed-load resulting from erosion and sedimentation results in a generally unstable bottom and extremely low invertebrate production.

No relationship has been identified in the streams between turbidity and fish biomass, but there appears to be a relationship between turbidity and species composition. Clear, cold water tributaries are dominated by Salmonidae in contrast to members of the family Cyprinidae which dominate the turbid, warm water reaches. The fry of rainbow smelt (*Osmerus mordax*), white suckers (*Catastomus commersoni*) and longnose suckers (*Catastomus catastomus*) were found to be numerous in spring drift samples, indicating that high spring turbidity levels in the Nemadji River have litte effect on the reproductive success of these species. Although adult game fish were identified in the Nemadji River, no drifting fry were recovered.

NON-POINT SOURCE MODELING FOR SECTION 208 PLANNING- Walter M. Sanders, III

Hydrologic unit models are very complex and require relatively large amounts of calibration data and computational time. Once developed, however, these detailed process models will simplify interfacing problems and provide optimum environmental management tools for state area-wide 208 agencies.

It is obvious that a large number of individual non-point source and water quality models representing wide ranges of complexities and possible applications are available. Greater progress, however, must be made in interfacing these models into environmental management packages. At present, however, compatible packages can be assembled to represent or simulate many local problems. And, even though these model packages are known to have deficiencies in certain areas, the judicious application of these models for simulating management alternatives using high-low and average conditions offers the best available assistance for the decision-making process.

TILE DRAIN SIMULATION MODEL

A. B. Bottcher

A computerized simulation model is being developed at Purdue University to provide a predictive tool for the determination of sediment losses from tile effluent. The model will provide a flow hydrograph with associated sediment loading as a function of the input variables (rainfall and initial soil moisture content). The model will have the capability of being modified to represent different tile system designs and soil types.

The need for concern of tile drainage influence on water quality is shown by the significant contribution it has to stream flow. Approximately 50% of the Black Creek Wateshed is drained by subsurface tile systems. A tile system can contribute anywhere from 10 to 100% (typically 30%) of the total runoff of a drained area. This indicates that approximately 15% of the runoff per year from Black Creek is tile effluent. During non-storm periods tile effluent is the major source for stream flow in agricultural areas. The influence of tile flow on stream flow may vary greatly depending on the annual rainfall distribution.

An estimate of the sediment, phosphorous and nitrogen going into the Maumee River from Black Creek tile effluent is approximately 100, 3 and 9 kilograms per hectare per year, respectively. Note that a kilogram per hectare is approximately equal to a pound per acre. This is based on the previous flow assumption and tile effluent data collected on about 266 tile outlets in the Black Creek Watershed. The loading rates of localized areas can be much larger as shown by G. O. Schwab (1) He measured annual sediment losses from tiles as high as 5400 kg/hect/year. His results indicate that in some critical areas the tile effluent may be the dominant effect on stream water quality.

Data collected for the single event on April 26-30 shows a sediment loss of approximately 6 kg/hectare. The peak concentration of suspended solids was 279 PPM. Tile outflow peaked at .0036 cubic meters/sec (~60 gal/min). Tile flow was caused by a 4.1 centimeters rain storm. The above data is in good agreement with data collected for several tile systems draining Hoytville soils in the Black Creek Watershed.

The tile erosion model with associated hydrologic model should be operational by August 1977. The laboratory determination of required relationships will begin in January, 1977. The hydrologic model is working for the linear assumptions presented in this paper. The tile sampling station is functioning and should be collecting water quality samples for the next year to determine tile effluents effect on stream water quality and provide a means to calibrate the drain tile erosion model.

BEST MANAGEMENT PRACTICES FOR URBAN STORM AND COMBINED SEWER POLLUTION CONTROL

A CASE STUDY

Cornelius B. Murphy, Jr.

The application of source and collection system management concepts serve as the basis for the application of a Best Management Practice (BMP) program relative to the abatement of urban storm and combined sewer pollution. These concepts have been evaluated for application to the Rochester, New York combined sewer system. The BMP program developed for Rochester will result in the development of a very cost/effective first phase solution for the Rochester combined sewer overflow abatement program. By working with the existing system and optimizing its operation, a better defined and optimally designed structural intensive second phase solution can be developed.

SIMULATION OF THE ENVIRONMENTAL IMPACT OF LAND USE ON WATER QUALITY

D. B. Beasley

This paper will discuss the steps involved in organizing and implementing a computerized model of an agricultural watershed for the purpose of studying the effects of land use and management on water quality. The concepts behind the model and the major operational equations are presented in a concise form.

The "distributed parameter" approach involves dividing and watershed into areas small enough to be considered uniform (soil type, slope, crop, etc.). The small areas or elements are modeled separately (using flow from upstream or uphill elements as inputs along with rainfall) and the outputs are routed through the watershed. The strengths of this approach are several. The actual processes occurring at a specific point in the watershed are being simulated. The output from the model can be collected at any point or many points in the watershed. Thirdly, although the data file necessary for simulation is rather complex, it is easily and quickly changed to reflect management or cropping changes. Finally, the sedimentation process can be described much more precisely. Two weaknesses are inherent in this model. First, it requires very large amounts or processor time and computer core to run. It is not capable of simulating long periods of record economically (thus it is limited to event or single storm simulations). Secondly, it requires more data for its descriptive data file (watershed description).

The element used in this model is a square-shaped area that is 330 feet on a side. This means that the element is exactly 2.5 acres or approximately 1 hectare in size. The topographic information (direction and magnitude of steepest slope) is obtained from USGS 7.5 minute quadrangles that have been photographically enlarged to a scale of 16 inches to the mile (1:3960) and then have been partitioned off using a 1 inch grid pattern.

Likewise, the field boundaries and soil types are taken from aerial photographs that have been similarily enlarged and divided into the same grid pattern. The model then divides the flow off of an element into its horizontal and vertical components (with respect to the map) and sends this output to the receiving element (s). No flow is routed to diagonally located elements.

The present model is designed to simulate the hydrologic processes that the original model did as well as these of tile drainage, channel or stream flow, and sedimentation. There is, however, a fundamental differences in the operation of the original model and the present model. The present model is written in the GASP IV Simulation Language format. GASP IV is a Fortran IV based, discrete-continuous simulation vehicle. It uses a Runge-Kutta-England integratio algorithm with a variable time step for solving differential equations.

Finally, the sediment transport rate due to flow (rainfall splash transport is neglected) is computed from the following equation,

$$TF = CTF - KTF - S^{1}.667 \frac{(Q)}{(DX)} 1.667 - DX - C3 \qquad (90$$

where : TF = sediment transport rate for an element.
CTF = management factor relating to transport,
KTF = transport factor related to particle size distribution and soil condition,
C3 = constant.

The constants C1, C2, and C3 are determined from a regression analysis of constants used to produce simulation output that adequately described rainulator runs in the Black Creek Study area for the soils and other factors in the target watersheds.

We hope this two day seminar session has been of some benefit to you. We are anxious to provide to you any and all data we have to help you meet the Section 208 mandate to have implementable plans for point and non-point source pollution control. Thank you for your interest and attendance at the seminar.

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